CERTIFICATE OF TRANSLATION

I, TAKESHI OSHIO, patent attorney of Fifteenth Floor, Crystal Tower, 1-2-27 Shiromi, Chuo-ku, Osaka 540-6015, Japan HEREBY CERTIFY that I am acquainted with the English and Japanese languages and that the attached English translation is a true English translation of what it purports to be, a translation of Japanese Patent Application No. 7-254043 on 29 September, 1995 in the name of SHARP KABUSHIKI KAISHA.

Dated this 10th day of October 2006

Takeshi Oshio

TAKESHI OSHIO

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[Title of the Invention]	TRANSMISSION TYPE LIQUID CRYSTAL DISPLAY DEVICE AND METHOD FOR FABRICATING THE SAME
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[Name of the Document] SPECIFICATION

[Title of the Invention] Transmission type liquid crystal display device and method for fabricating the same

[Claims]

[Claim 1] A transmission type liquid crystal display device having switching elements each arranged near a crossing of a scanning line and a signal line, a scanning electrode of the switching element being connected to the scanning line, an electrode of the switching element other than the scanning electrode being connected to the signal line, and the other electrode of the switching element being connected to a pixel electrode,

wherein an interlayer insulating film made of an organic thin film with high transparency is formed above the switching elements, the scanning lines, and the signal lines, and

the pixel electrodes made of a transparent conductive film are formed above the interlayer insulating film.

[Claim 2] A transmission type liquid crystal display device including scanning lines and signal lines formed to cross each other and switching elements each arranged near a crossing of the scanning line and the signal line, a scanning electrode of the switching element being connected to the scanning line, an electrode of the switching element other than the scanning electrode being connected to the signal line, and the

other electrode of the switching element other than the scanning electrode being connected to a pixel electrode via a connecting electrode,

wherein an interlayer insulating film made of an organic thin film with high transparency is formed above the switching elements, the scanning lines, the signal lines, and the connecting lines,

the pixel electrodes made of a transparent conductive film are formed above the interlayer insulating film so that at least a portion of each of the pixel electrodes overlaps at least one of at least the scanning line and the signal line, and

the connecting electrode and the pixel electrode are connected with each other via a contact hole formed through the interlayer insulating film.

[Claim 3] A transmission type liquid crystal display device according to claim 1 or 2, wherein the interlayer insulating film is made of a photosensitive acrylic resin.

[Claim 4] A transmission type liquid crystal display device according to any of claims 1 to 3, wherein the interlayer insulating film is made of a resin which is made transparent by optical or chemical decoloring treatment.

[Claim 5] A transmission type liquid crystal display device according to claim 1 or 2, wherein the pixel electrode overlaps at least one of the signal line and the scanning line overlap by 1 μm or more in a line width direction.

[Claim 6] A transmission type liquid crystal display device according to any of claims 1 to 4, wherein the thickness of the interlayer insulating film is 1.5 μm or more.

[Claim 7] A transmission type liquid crystal display device according to claim 2, wherein the connecting electrode is formed of a transparent conductive film.

[Claim 8] A transmission type liquid crystal display device according to claim 2, wherein the contact hole is formed above either a storage capacitor line or the scanning line.

[Claim 9] A transmission type liquid crystal display device according to claim 2 or 8, wherein a metal nitride layer is formed below the contact hole to connect the connecting electrode and the pixel electrode.

[Claim 10] A transmission type liquid crystal display device according to claim 1 or 2, wherein a capacitance ratio represented by expression (1):

$$\text{Capacitance ratio} = C_{sd} / (C_{sd} + C_{ls} + C_s) \quad \ldots(1)$$

is 10% or less, wherein C_{sd} denotes a capacitance value between the pixel electrode and the source signal line, C_{ls} denotes a capacitance value of a liquid crystal portion corresponding to each pixel in an intermediate display state, and C_s denotes a capacitance value of the storage capacitor of each pixel.

[Claim 11] A transmission type liquid crystal

display device according to any of claims 1, 2, 5, 6, and 10, wherein the shape of the pixel electrode is rectangular with a side parallel to the signal line being longer than a side parallel to the scanning line.

[Claim 12] A transmission type liquid crystal display device according to claim 1 or 2, further comprising a display driving circuit for supplying a data signal of which polarity is inverted every scanning line to the signal line, to be supplied to the pixel electrode via the switching element.

[Claim 13] A method for fabricating a transmission type liquid crystal display device, comprising the steps of:

forming a plurality of switching elements in a matrix on a substrate, forming a scanning line connected to a scanning electrode of each of the switching elements and a signal line connected to an electrode of the switching element other than the scanning electrode so as to cross each other, and forming a connecting electrode made of a transparent electrode connected to the other electrode of the switching element other than the scanning electrode;

forming an organic thin film with high transparency above the switching elements, the scanning lines, the signal lines, and the connecting lines by a coating method and patterning the organic thin film to form an interlayer insulating film and forming contact holes through the interlayer insulating film to reach the connecting electrodes; and

forming pixel electrodes made of transparent conductive films on the interlayer insulating film and

inside the contact holes so that at least a portion of each of the pixel electrodes overlaps at least one of at least the scanning line and the signal line.

[Claim 14] A method for fabricating a transparent type liquid crystal display device according to claim 13, wherein the patterning of the interlayer insulating film is conducted by light exposure and development or by an etching process after the formation of a photoresist on the interlayer insulating film.

[Claim 15] A method for fabricating a transmission type liquid crystal display device, comprising the steps of:

forming a plurality of switching elements in a matrix on a substrate, forming a scanning line connected to a scanning electrode of each of the switching elements and a signal line connected to an electrode of the switching element other than the scanning electrode so as to cross each other, and forming a connecting electrode made of a transparent electrode connected to the other electrode of the switching element other than the scanning electrode;

forming a photosensitive transparent acrylic resin of which light-exposed portion dissolves in a developing solution above the switching elements, the scanning lines, the signal lines, and the connecting lines, allowing the acrylic resin to be subjected to light exposure and development to form an interlayer insulating film, and forming contact holes through the interlayer insulating film to reach the connecting electrodes; and

forming pixel electrodes formed of transparent

conductive films on the interlayer insulating film and inside the contact holes so that at least a portion of each of the pixel electrodes overlaps at least one of at least the scanning line and the signal line.

[Claim 16] A method for fabricating a transmission type liquid crystal display device according to claim 13 or 15, wherein after the light exposure and the development of the interlayer insulating film, the entire substrate is exposed to light for a photosensitive agent used for the photosensitive transparent acrylic resin.

[Claim 17] A method for fabricating a transmission type liquid crystal display device according to any of claims 15 to 16, wherein a base polymer of the photosensitive transparent acrylic resin is a polymer of methacrylic acid and glycidyl methacrylate, and the photosensitive transparent acrylic resin contains a naphthoxy diazide positive-type photosensitive agent as the photosensitive agent.

[Claim 18] A method for fabricating a transmission type liquid crystal display device according to any of claims 15 to 17, wherein the photosensitive transparent acrylic resin for forming the interlayer insulating film has a light transmittance of 90% or more for transmitting light with a wavelength in the range of 400 to 800 nm.

[Claim 19] A method for fabricating a transmission type liquid crystal display device according to any of claims 15 to 18, wherein the photosensitive transparent acrylic resin has a thickness of about 1.5 μm or

more.

[Claim 20] A method for fabricating a transmission type liquid crystal display device according to any of claims 15 to 19, wherein a surface of the substrate is irradiated with ultraviolet light before the formation of the photosensitive transparent acrylic resin, and then the interlayer insulating film is formed of the photosensitive transparent acrylic resin.

[Claim 21] A method for fabricating a transmission type liquid crystal display device according to any of claims 13 to 20, wherein after the formation of the interlayer insulating film of the photosensitive transparent acrylic resin, the surface of the photosensitive transparent acrylic resin is ashed under an oxygen plasma atmosphere.

[Claim 22] A method for fabricating a transmission type liquid crystal display device according to claim 21, wherein the thickness of the ashed portion under the oxygen plasma atmosphere is controlled to the range of 1000 to 5000 angstrom.

[Claim 23] A method for fabricating a transmission type liquid crystal display device according to claim 13 or 14, wherein the thickness of the pixel electrode is 500 angstrom or more.

[Claim 24] A method for fabricating a transmission type liquid crystal display device according to any of claims 15 to 21, wherein the photosensitive transparent acrylic resin is developed with 0.1 to 1.0 mol% of a

tetramethyl ammonium hydroxyoxide developing solution to form the interlayer insulating film.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to a transmission type liquid crystal display device which is used for displays of computers, TV sets, and the like and includes switching elements such as thin film transistors (hereinafter, referred to as "TFTs") as addressing elements, and a method for fabricating the same.

[0002]

[Prior Art]

Figure 14 is a circuit diagram of a conventional transmission type liquid crystal display device provided with an active matrix substrate.

[0003]

Referring to Figure 14, the active matrix substrate includes a plurality of pixel electrodes 1 arranged in a matrix and TFTs 2 used as switching elements connected to the respective pixel electrodes 1. Gate electrodes of the TFTs 2 are connected to gate signal lines 3 as scanning lines, so that gate signals can be input into the gate electrodes to control the driving of the TFTs 2. Source electrodes of the TFTs 2 are connected to source signal lines 4 as signal lines, so that data (display) signals can be input into the corresponding pixel electrodes 1 via the TFTs 2 when the TFTs 2 are being driven. The gate signal lines 3 and the source signal lines 4 run along peripheries of the pixel elec-

trodes 1 arranged in a matrix to cross each other. Drain electrodes of the TFTs 2 are connected to the respective pixel electrodes 1 and storage capacitors 5. Counter electrodes of the storage capacitors 5 are connected to common lines 6.

[0004]

Figure 15 is a sectional view of a one-TFT portion of the active matrix substrate of the conventional liquid crystal display device.

[0005]

Referring to Figure 15, a gate electrode 12 connected to the gate signal line 3 shown in Figure 14 is formed on a transparent insulating substrate 11. A gate insulating film 13 is formed covering the gate electrode. A semiconductor layer 14 is formed on the gate insulating film so as to overlap the gate electrode 12 via the gate insulating film, and a channel protection layer 15 is formed on the center of the semiconductor layer. n^+-Si layers as a source electrode 16a and a drain electrode 16b are formed covering the end portions of the channel protection layer 15 and portions of the semiconductor layer 14, so that they are separated from each other at the top of the channel protection layer 15. A metal layer 17a which is to be the source signal line 4 shown in Figure 14 is formed to overlap the source electrode 16a as one of the n^+-Si layers. A metal layer 17b is formed to overlap the drain electrode 16b as the other n^+-Si layer so as to connect the drain electrode 16b and the pixel electrode 1. An interlayer insulating film 18 is formed covering the TFT 2, the gate signal line 3, and the source signal line 4.

[0006]

A transparent conductive film is formed on the interlayer insulating film 18 to constitute the pixel electrode 1. The transparent conductive film is connected to the metal layer 17b which is in contact with the drain electrode 16b of the TFT 2 via a contact hole 19 formed through the interlayer insulating film 18.

[0007]

Thus, since the interlayer insulating film 18 is formed between the gate and source lines 3 and 4 and the transparent conductive film which is to be the pixel electrode 1, it is possible to overlap the pixel electrode 1 with the lines 3 and 4. Such a structure is disclosed in Japanese Laid-Open Patent Publication No. 58-172685, for example. With this structure, the aperture ratio improves and, since the electric field generated by the lines 3 and 4 is shielded, the occurrence of disclination can be minimized.

[0008]

Conventionally, the interlayer insulating film 18 is formed by depositing an inorganic material such as silicon nitride (SiN) to a thickness of about 5000 angstrom by CVD.

[0009]

[Problems to be Solved by the Invention]

When a transparent insulating film made of SiN_x, SiO_2, TaO_x, and the like is formed on the interlayer insulating film 18 by CVD or sputtering, the surface of the film directly reflects the surface profile of the underlying film. Therefore, when the pixel electrode 1

is formed on the transparent insulating film, steps will be formed on the pixel electrode if the underlying film has steps, causing disturbance in the orientation of liquid crystal molecules. Alternatively, the interlayer insulating film may be formed by applying an organic material such as polyimide to obtain a flat pixel portion. In such a case, however, in order to form the contact holes for electrically connecting the pixel electrodes and the drain electrodes, a series of steps including photo-patterning using a photoresist as a mask, etching for forming the contact holes, and removal of the photoresist are required. A photosensitive polyimide film may be used to shorten the etching and removal steps. In this case, however, the resultant interlayer insulating film appears colored. This is not suitable for a liquid crystal display device requiring high light transmission and transparency.

[0010]

Another disadvantage is as follows. The pixel electrode 1 overlaps the gate signal line 3 and the source signal line 4 by forming via the interlayer insulating film 18 between the lines 3 and 4, increasing the aperture ratio of the resultant liquid crystal display device. In such an overlap structure of the lines 3 and 4 and the pixel electrode 1, the capacitances between the pixel electrode 1 and the lines 3 and 4 increase. In particular, when an inorganic film made of silicon nitride and the like is used, the dielectric constant of such a material is as high as 8 and, since the film is formed by CVD, the thickness of the resultant film is as small as about 5000 angstrom. With such a thin interlayer insulating film, the capacitances between the

pixel electrode 1 and the lines 3 and 4 are large. This causes the following problems (1) and (2). Incidentally, in order to obtain a thicker inorganic film made of silicon nitride and the like, an undesirably long time is required in the aspect of the fabrication process.

[0011]

(1) When the pixel electrode 1 overlaps the source signal line 4, the capacitance between the pixel electrode 1 and the source signal line 4 becomes large. This increases the signal transmittance, and thus a data signal held in the pixel electrode 1 during a holding period fluctuates depending on the potential thereof. As a result, the effective voltage applied to the liquid crystal in the pixel varies, causing, in particular, vertical crosstalk toward a pixel adjacent in the vertical direction in the actual display.

[0012]

In order to reduce the influence of the capacitance between the pixel electrode 1 and the source signal line 4 appearing on the display, Japanese Laid-Open Patent Publication No. 6-230422 proposes a driving method where the polarity of a data signal to be supplied to the pixels is inverted every source signal line. This driving method is effective for a black-and-white display panel where the displays adjacent pixels are highly correlated with each other. However, it is not effective for a color display panel for normal notebook type personal computers and the like where pixel electrodes are arranged in a vertical stripe shape (in color display, a square pixel is divided into three vertically long rectangular picture elements representing R, G, and

B, forming a vertical stripe shape). The display color of pixels connected to one source signal line 4 is different from that of pixels connected to an adjacent source signal line. Accordingly, the above method of inverting the polarity of the data signal every source signal line is not effective in reducing vertical crosstalk for the general color display, though it is effective for the black-and-white display.

[0013]

(2) When the pixel electrode 1 overlaps the gate signal line 3 for driving the pixel, the capacitance between the pixel electrode 1 and the gate line 3 becomes large, increasing the feedthrough of the write voltage to the pixel due to a switching signal for controlling the TFT 2.

[0014]

In order to solve the above problems, an objective of the present invention is to provide a transmission type liquid crystal display device where flat pixel electrodes overlap respective lines to improve the aperture ratio of the liquid crystal display, minimize disturbance in the orientation of liquid crystal, and simplify the fabrication process, and the influence of the capacitance between the pixel electrodes and the lines appearing on the display, such as crosstalk, can be reduced to achieve a good display, and a method for fabricating the same.

[0015]

[Means for Solving the Problems]

The transmission type liquid crystal display

device according to the present invention has switching elements each arranged near a crossing of a scanning line and a signal line, a scanning electrode of the switching element being connected to the scanning line, an electrode of the switching element other than the scanning electrode being connected to the signal line, and the other electrode of the switching element being connected to a pixel electrode, wherein an interlayer insulating film made of an organic thin film with high transparency is formed above the switching elements, the scanning lines, and the signal lines, and the pixel electrodes made of a transparent conductive film are formed above the interlayer insulating film, whereby the above objective is attained.

[0016]

Preferably, the transmission type liquid crystal display device according to the present invention includes scanning lines and signal lines formed to cross each other and switching elements each arranged near a crossing of the scanning line and the signal line, a scanning electrode of the switching element being connected to the scanning line, an electrode of the switching element other than the scanning electrode being connected to the signal line, and the other electrode of the switching element other than the scanning electrode being connected to a pixel electrode via a connecting electrode so that a data signal is supplied to the pixel electrode via the switching element to realize liquid crystal display, wherein an interlayer insulating film made of an organic thin film with high transparency is formed above the switching elements, the scanning lines, the signal lines, and the connecting lines, the pixel

electrodes made of a transparent conductive film are formed above the interlayer insulating film so that at least a portion of the pixel electrode overlaps at least one of at least the scanning line and the signal line, and the connecting electrode and the pixel electrode are connected with each other via a contact hole formed through the interlayer insulating film, whereby the above objective is attained.

[0017]

Preferably, the interlayer insulating film is made of a photosensitive acrylic resin.

[0018]

The interlayer insulating film may be made of a resin which is made transparent by optical or chemical decoloring treatment.

[0019]

The pixel electrode may overlap at least one of the signal line and the scanning line by 1 μm or more in a line width direction.

[0020]

The thickness of the interlayer insulating film is desirably 1.5 μm or more.

[0021]

The connecting electrode is desirably formed of a transparent conductive film.

[0022]

The contact hole is desirably formed above either

a storage capacitor line constituting each pixel or the scanning line.

[0023]

A metal nitride layer is desirably formed below the contact hole to connect the connecting electrode and the pixel electrode.

[0024]

The capacitance ratio represented by expression (1) above is desirably 10% or less.

[0025]

The pixel electrodes may be arranged in a vertical strip shape, and the shape of each pixel electrode may be rectangular with a side parallel to the signal line being longer than a side parallel to the scanning line.

[0026]

The method for driving the transmission type liquid crystal display device includes inverting the polarity of a data signal supplied from the signal line every scanning line, whereby the above objective is attained.

[0027]

The method for fabricating a transmission type liquid crystal display device according to the present invention includes the steps of: forming a plurality of switching elements in a matrix on a substrate, forming a scanning line connected to a scanning electrode of each of the switching elements and a signal line connected to

an electrode of the switching element other than the scanning electrode so as to cross each other, and forming a connecting electrode made of a transparent electrode connected to the other electrode of the switching element other than the scanning electrode; forming an organic thin film with high transparency above the switching elements, the scanning lines, the signal lines, and the connecting lines by a coating method and patterning the organic thin film to form an interlayer insulating film and forming contact holes through the interlayer insulating film to reach the connecting electrodes; and forming pixel electrodes made of transparent conductive films on the interlayer insulating film and inside the contact holes so that at least a portion of each of the pixel electrodes overlaps at least one of at least the scanning line and the signal line, whereby the above objective is attained.

[0028]

Preferably, in the method for fabricating a transparent type liquid crystal display device according to the present invention, the patterning of the interlayer insulating film is conducted by exposure and development or by an etching process after the formation of a photoresist on the interlayer insulating film.

[0029]

More specifically, the method for fabricating a transmission type liquid crystal display device according to the present invention includes the steps of: forming a plurality of switching elements in a matrix on a transparent insulating substrate, forming a scanning line connected to a scanning electrode of each of the switch-

ing elements and a signal line connected to an electrode of the switching element other than the scanning electrode so as to cross each other, and forming a connecting electrode made of a transparent conductive film connected to the other electrode of the switching element other than the scanning electrode; forming a photosensitive resin above the switching elements, the scanning lines, the signal lines, and the connecting lines by a coating method and patterning by light exposure and alkaline development to form an interlayer insulating film and forming contact holes through the interlayer insulating film to reach the connecting electrodes; and forming pixel electrodes made of transparent conductive films on the interlayer insulating film and inside the contact holes so that at least a portion of each of the pixel electrodes overlaps at least one of at least the scanning line and the signal line.

[0030]

Alternatively, more specifically, the method for fabricating a transmission type liquid crystal display device according to the present invention includes the steps of: forming a plurality of switching elements in a matrix on a transparent insulating substrate, forming a scanning line connected to a scanning electrode of each of the switching elements and a signal line connected to an electrode of the switching element other than the scanning electrode so as to cross each other, and forming a connecting electrode made of a transparent conductive film connected to the other electrode of the switching element other than the scanning electrode; forming an organic thin film above the switching elements, the scanning lines, the signal lines, and the connecting

lines, forming a photoresist on the organic thin film, and patterning by an etching process to form an interlayer insulating film and forming contact holes through the interlayer insulating film to reach the connecting electrodes; and forming pixel electrodes made of transparent conductive films on the interlayer insulating film and inside the contact holes so that at least a portion of each of the pixel electrodes overlaps at least one of at least the scanning line and the signal line.

[0031]

The method for fabricating a transmission type liquid crystal display device according to the present invention includes the steps of: forming a plurality of switching elements in a matrix on a substrate, forming a scanning line connected to a scanning electrode of each of the switching elements and a signal line connected to an electrode of the switching element other than the scanning electrode so as to cross each other, and forming a connecting electrode made of a transparent electrode connected to the other electrode of the switching element other than the scanning electrode; forming a photosensitive transparent acrylic resin of which light-exposed portion dissolves in a developing solution above the switching elements, the scanning lines, the signal lines, and the connecting lines, allowing the acrylic resin to be subjected to light exposure and development to form an interlayer insulating film, and forming contact holes through the interlayer insulating film to reach the connecting electrodes; and forming pixel electrodes formed of transparent conductive films on the interlayer insulating film and inside the contact holes so that at

least a portion of each of the pixel electrodes overlaps at least one of at least the scanning line and the signal line, whereby the above objective is attained.

[0032]

Preferably, in the method for fabricating a transmission type liquid crystal display device according to the present invention, after the light exposure and the development of the interlayer insulating film, the entire substrate is exposed to light for a photosensitive agent used for the photosensitive transparent acrylic resin, so as to completely react unnecessary photosensitive agent.

[0033]

Preferably, in the method for fabricating a transmission type liquid crystal display device according to the present invention, a base polymer of the photosensitive transparent acrylic resin is a polymer of methacrylic acid and glycidyl methacrylate, and the photosensitive transparent acrylic resin contains a naphthoxy diazide positive-type photosensitive agent as the photosensitive agent.

[0034]

Preferably, the method for fabricating a transmission type liquid crystal display device according to the present invention, the photosensitive transparent acrylic resin for forming the interlayer insulating film has a light transmittance of 90% or more for transmitting light with a wavelength in the range of 400 to 800 nm.

[0035]

Preferably, in the method for fabricating a transmission type liquid crystal display device according to the present invention, the photosensitive transparent acrylic resin has a thickness of about 1.5 μm or more.

[0036]

Preferably, in the method for fabricating a transmission type liquid crystal display device according to the present invention, a surface of the substrate is irradiated with ultraviolet light before the formation of the photosensitive transparent acrylic resin, and then the interlayer insulating film is formed of the photosensitive transparent acrylic resin.

[0037]

Preferably, in the method for fabricating a transmission type liquid crystal display device according to the present invention, after the formation of the interlayer insulating film of the photosensitive transparent acrylic resin, the surface of the photosensitive transparent acrylic resin is ashed under an oxygen plasma atmosphere.

[0038]

Preferably, in the method for fabricating a transmission type liquid crystal display device according to the present invention, the thickness of the ashed portion by the oxygen plasma is controlled to the range of 1000 to 5000 angstrom.

[0039]

Preferably, in the method for fabricating a transmission type liquid crystal display device according

to the present invention, the thickness of the pixel electrode is 500 angstrom or more.

[0040]

Preferably, In the method for fabricating a transmission type liquid crystal display device according to the present invention, the photosensitive transparent acrylic resin is developed with 0.1 to 1.0 mol% of a tetramethyl ammonium hydroxyoxide developing solution to form the interlayer insulating film.

[0041]

The function of the liquid crystal display device with the above configuration will be described.

[0042]

According to the present invention, the interlayer insulating film is formed above the switching elements, the scanning lines, and the signal lines, and the pixel electrodes are formed on the interlayer insulating film, so that each of the pixel electrode is connected to the other electrode of the TFT via the connecting electrode and the contact hole formed through the interlayer insulating film. With the existence of the interlayer insulating film, the pixel electrode can be formed to overlap the corresponding lines. This improves the aperture ratio and minimizes disturbances in the orientation of the liquid crystal. Since the interlayer insulating film is composed of an organic thin film made of a photosensitive acrylic resin and the like, a high-quality film with a smaller dielectric constant and higher transparency can be obtained with good productivity, compared with an inorganic thin film such

as silicon nitride film conventionally used. This makes it possible to increase the thickness of the film. Thus, the capacitances between the pixel electrode and the lines can be reduced, and the signal transmittance is suppressed. As a result, the influence such as crosstalk on the display caused by the capacitance component between the pixel electrode and the lines can be reduced, providing better display.

The pixel electrode is connected to the other electrode of the switching element other than the scanning electrode via the connecting electrode. Therefore, a connecting portion such as the contact hole formed through the interlayer insulating film can be easily formed even when the TFT is small.

[0043]

The interlayer insulating film is formed by applying a photosensitive organic material such as an acrylic resin to the substrate by a coating method and patterning by light exposure and alkaline development to obtain an organic thin film with a thickness of several micrometers with high productivity. This can also be obtained by forming the organic thin film by deposition, forming a photoresist on the organic thin film, and patterning the organic thin film in an etching process.

[0044]

When the resin as the material for the interlayer insulating film is colored, the resin can be made transparent by an optical or chemical decoloring treatment after the patterning.

[0045]

The aperture ratio can be maximized by overlapping the pixel electrode with the lines by 1 μm or more. With this overlap, the processing precision of the pixel electrode with respect to the lines may not be so high, because as long as the pixel electrode overlaps the lines, light leakage is blocked by the lines even when the processing precision is not so high.

[0046]

When the thickness of the interlayer insulating film is 1.5 μm or more, the capacitance between the lines and the pixel electrode is sufficiently small and the time constant is small even if the overlap of the pixel electrode with the lines is 1 μm or more. This further reduces the influence of the capacitance component on the display, such as crosstalk, providing better display.

[0047]

The aperture ratio further improves by using a transparent conductive film for the connecting electrode for connecting the other electrode of the TFT to the pixel electrode.

[0048]

By forming the contact hole through the interlayer insulating film above the light-shading storage capacitor line or the scanning line, light leakage due to disturbances in the orientation of the liquid crystal occurs in the light-shading portion, not the aperture portion. This prevents the contrast from lowering.

[0049]

By forming the metal nitride layer below the contact hole formed through the interlayer insulating film, the adhesion between the interlayer insulating film and the underlying layer increases.

[0050]

By reducing the capacitance ratio represented by expression (1) above to 10% or less, good display can be obtained since the capacitance between the pixel electrode and the source electrode is sufficiently reduced.

[0051]

By applying the present invention, the influence of the capacitance component on the display, such as vertical crosstalk, can be eliminated to obtain good display even when each pixel electrode is of a rectangular shape with the side thereof parallel to the source signal line being longer than the side thereof parallel to the scanning signal line.

[0052]

The influence of the capacitance between the source signal line and the pixel electrode can be further reduced by inverting the polarity of a data signal supplied from the source signal line every scanning signal line.

[0053]

The comparatively thick interlayer insulating film used in the present invention can be made flat. Therefore, conventional troubles caused by steps formed by the underlying lines and the like, such as disconnec-

tion on the drain side of the pixel electrode, are overcome. Disturbances in the orientation of the liquid crystal due to steps are also prevented. The pixel electrodes and the lines are isolated by the interlayer insulating film formed therebetween. This greatly reduces the number of defective pixels due to electrical leakage between the pixel electrodes and the signal lines, thereby increasing production yield and reducing production cost. Moreover, according to the present invention, the interlayer insulating film can be formed only by the resin formation step, instead of the film formation step, the pattern formation step with a photoresist, the etching step, the resist removing step, and the cleaning step conventionally required. This simplifies the fabrication process and reduces production cost.

[0054]

The entire substrate may be exposed to light to allow the remaining unnecessary photosensitive agent contained in the photosensitive transparent acrylic resin to completely react after the light exposure and development of the interlayer insulating film. With this process, an interlayer insulating film with higher transparency can be obtained.

[0055]

The surface of the substrate before the formation of the interlayer insulating film may be irradiated with ultraviolet light. This improves the adhesion between the interlayer insulating film and the underlying film. Thus, the resultant device can be stable against further processing in the production process.

[0056]

The surface of the interlayer insulating film may be ashed under an oxygen plasma atmosphere before the formation of the film of pixel electrode material thereon. This improves the adhesion of the interlayer insulating film and the film of the pixel electrode material formed thereon. Thus, the resultant device can be stable against further processing in the production process.

[0057]

The pixel electrodes with a thickness of 500 angstrom or more can effectively prevent an agent used as a removing solution from permeating from gaps of the film surface into the resin and the resin from expanding due to the permeation of the agent.

[0058]

According to the present invention, the pixel electrode becomes large by eliminating a margin conventionally formed between the pixel electrode and the lines. As a result, the aperture ratio of the display improves, and thus the brightness thereof improves, increasing the contrast. Accordingly, the viewing angle can be widened by reducing the retardation without degrading the contrast. This makes it possible to obtain a significantly wide viewing angle.

[0059]

[Embodiments of the Invention]

Hereinbelow, the embodiments of the invention will be described.

[0060]

(Embodiment 1)

Figure 1 is a plan view of a one-pixel portion of an active matrix substrate of the transmission type liquid crystal display device of Embodiment 1 according to the present invention.

[0061]

Referring to Figure 1, the active matrix substrate includes a plurality of pixel electrodes 21 arranged in a matrix. Gate signal lines 22 as scanning lines and source signal lines 23 as signal lines run surround the peripheries of the pixel electrodes 21 so as to cross each other. The peripheries of each pixel electrode 21 overlap the gate signal lines 22 and the source signal lines 23. A TFT 24 acting as a switching element connected to the corresponding pixel electrode 21 is formed at a crossing of the gate signal line 22 and the source signal line 23. A gate electrode of the TFT 24 is connected to the gate signal line 22 so that a signal can be input into the gate electrode to control the driving of the TFT 24. A source electrode of the TFT 24 is connected to the source signal line 23 so that a data signal can be input into the source electrode of the TFT 24. A drain electrode of the TFT 24 is connected to the pixel electrode 21 via a connecting electrode 25 and a contact hole 26. The drain electrode is also connected to an electrode 25a of a storage capacitor via the connecting electrode 25. The other electrode 27 of the storage capacitor is connected to a common line.

[0062]

Figure 2 is a sectional view of the active matrix

substrate of the transparent type liquid crystal display device taken along line A-A' of Figure 1.

[0063]

Referring to Figure 2, a gate electrode 32 connected to the gate signal line 22 shown in Figure 1 is formed on a transparent insulating substrate 31. A gate insulating film 33 is formed covering the gate electrode. A semiconductor layer 34 is formed on the gate insulating film so as to overlap the gate electrode 32 via the gate insulating film, and a channel protection layer 35 is formed on the center of the semiconductor layer. n^+-Si layers as a source electrode 36a and a drain electrode 36b are formed covering the end portions of the channel protection layer 35 and portions of the semiconductor layer 34, so that they are separated from each other by a portion of the channel protection layer 35. A transparent conductive film 37c and a metal layer 37b which are to be the double-layer source signal line 23 are formed to overlap the source electrode 36a as one of the n^+-Si layers. A transparent conductive film 37a' and a metal layer 37b' are formed to overlap the drain electrode 36b as the other n^+-Si layer. The transparent conductive film 37a' extends to connect the drain electrode 36b and the pixel electrode 21 and also serves as the connecting electrode 25 which is connected to the electrode 25a of the storage capacitor. An interlayer insulating film 38 is formed covering the TFT 24, the gate line 22, the source line 23, and the connecting electrode 25.

[0064]

A transparent conductive film is formed on the

interlayer insulating film 38 to constitute the pixel electrode **21**. The pixel electrode is connected to the drain electrode **36b** of the TFT **24** via the contact hole **26** formed through the interlayer insulating film 38 and the transparent conductive film **37a'** which is the connecting electrode **25**.

[0065]

The active matrix substrate in Embodiment 1 with the above structure is fabricated as follows.

[0066]

First, the gate electrode **32**, the gate insulating film **33**, the semiconductor layer **34**, the channel protection layer **35**, and the n^+-Si layers as the source electrode **36a** and the drain electrode **36b** are sequentially formed in this order on the transparent insulating substrate **31** such as a glass substrate. This film formation step can be conducted following a conventional method for fabricating an active matrix substrate.

[0067]

Thereafter, the transparent conductive films **37a** and **37a'** and the metal layers **37b** and **37b'** constituting the source signal line **23** and the connecting electrode **25** are sequentially formed by sputtering and are patterned into a predetermined shape.

[0068]

A photosensitive acrylic resin is applied to the resultant substrate to a thickness of 3 µm, for example, by spin coating to form the interlayer insulating film **38**. The resultant resin layer is exposed to light

according to a predetermined pattern and developed with an alkaline solution. Only portions of the resin layer exposed to light are etched with the alkaline solution, forming the contact holes 26 through the interlayer insulating film 38.

[0069]

Subsequently, a transparent conductive film is formed on the resultant substrate by sputtering and is patterned to form the pixel electrodes 21. Each pixel electrode 21 is thus connected to the corresponding transparent conductive film 37a' which is in contact with the drain electrode 36b of the TFT 24 via the contact hole 26 formed through the interlayer insulating film 38. In this way, the active matrix substrate in Embodiment 1 is fabricated.

[0070]

The thus-fabricated active matrix substrate includes the thick interlayer insulating film 38 between the pixel electrode 21 and the underlying layers including the gate signal line 22, the source signal line 23, and the TFT 24. With this thick interlayer insulating film, it is possible to overlap the pixel electrode 21 with the lines 22 and 23 and the TFT 24. Also, the surface of the pixel electrode 21 can be made flat. As a result, when the transmission type liquid crystal display device including the thus-fabricated active matrix substrate and a counter substrate with a liquid crystal layer therebetween is completed, the aperture ratio of this device can be improved. Also, since the electric field generated at the lines 22 and 23 can be shielded, the occurrence of disclination can be mini-

mized.

[0071]

The acrylic resin constituting the interlayer insulating film 38 has a dielectric constant of 3.4 to 3.5 which is lower than that of an inorganic film (the dielectric constant of silicon nitride is 8) and a high transparency. Also, since the spin coating is employed, a thickness as large as 3 μm can be easily obtained. This reduces the capacitances between the gate signal line 22 and the pixel electrode 21 and between the source signal lines 23 and the pixel electrodes 21, lowering the time constant. As a result, the influence of the capacitances between the lines 22 and 23 and the pixel electrode 21 appearing on the display, such as crosstalk, can be reduced, and thus a good and bright display can be obtained. The contact hole 26 can be formed into a sharp tapered shape by the patterning including the exposure to light and the alkaline development. This facilitates a better connection between the pixel electrode 21 and the transparent conductive film 37a'. Further, since the photosensitive acrylic resin is used, the thick film having a thickness of several micrometers can be easily formed by spin coating. No photoresist process is required at the patterning step. This is advantageous in production. Though the acrylic resin used as the interlayer insulating film 38 is colored before the coating, it can be made transparent optically by exposing the entire surface to light after the patterning step. The resin can also be made transparent chemically.

[0072]

In this embodiment, the transparent conductive

film 37a' is formed as the connecting electrode 25 connecting the drain electrode 36b of each TFT 24 and the corresponding pixel electrode 21. This is advantageous in the following points. In the conventional active matrix substrate, the connecting electrode is composed of a metal layer. When such a metal connecting electrode is formed in the aperture portion, the aperture ratio is lowered. In order to overcome this problem, the connecting electrode is conventionally formed above the TFT or the drain electrode of the TFT. The contact hole is formed above the connecting electrode through the interlayer insulating film to connect the drain electrode of the TFT and the pixel electrode. With this conventional structure, however, when the TFT is made smaller to improve the aperture ratio, for example, it is not possible to accommodate the entire contact hole above the smaller TFT. As a result, the aperture ratio lowers. When the thickness of the interlayer insulating film is made as large as several micrometers, the contact hole should be tapered in order to connect the pixel electrode and the underlying connecting electrode, and a large-size connecting electrode is required in the TFT region. For example, when the diameter of the contact hole is 5 μm, the size of the connecting electrode should be about 14 μm in consideration of the tapered contact hole and the alignment allowance. In the conventional active matrix substrate, if a TFT with a size smaller than this value is realized, the oversized connecting electrode causes a new problem of lowering the aperture ratio. In contrast, in the active matrix substrate of Embodiment 1, since the connecting electrode 25 is composed of the transparent conductive film 37a', no trouble of lowering the aperture ratio arises. Further, in this embodiment,

the connecting electrode 25 extends to connect the drain electrode 36b of the TFT and the electrode 25a of the storage capacitor formed by the transparent conductive film 37a'. Since the extension is also formed of the transparent conductive film 37a', it does not lower the aperture ratio, either.

[0073]

In this embodiment, the source signal line 23 is of a double-layer structure. If part of the metal layer 37b constituting the source signal line 23 is defective, the source signal line 23 can remain electrically conductive through the transparent conductive film 37a, so that the occurrence of disconnection of the source signal line can be reduced.

[0074]

(Embodiment 2)

In Embodiment 2, another method for forming the interlayer insulating film 38 will be described.

[0075]

First, a non-photosensitive organic thin film is formed by spin coating. A photoresist is then formed on the thin film and patterned. Using the patterned photoresist, the organic thin film is etched to obtain the interlayer insulating film 38 and the contact holes 26 formed through the interlayer insulating film 38.

[0076]

Alternatively, the non-photosensitive organic thin film may be deposited. A photoresist is then formed

on the thin film and patterned. Using the patterned photoresist, the organic thin film is etched to obtain the interlayer insulating film 38.

[0077]

Using the active matrix substrate with the thus-formed interlayer insulating film 38, a transmission type liquid crystal display device with a high aperture ratio can be realized, as in the active matrix substrate in Embodiment 1.

[0078]

The non-photosensitive organic thin film used as the interlayer insulating film 38 in this embodiment has a low dielectric constant and a high transparency. The thickness can be as large as 3 μm. With the low dielectric constant and the long distance between electrodes of the capacitance, the capacitances between the gate signal line 22 and the pixel electrode 21 and between the source signal line 23 and the pixel electrode 21 can be reduced.

[0079]

(Embodiment 3)

Figure 3 is a plan view of a one-pixel portion of an active matrix substrate of the transmission type liquid crystal display device of Embodiment 3 according to the present invention. Figure 4 is a sectional view of an active matrix substrate of the transmission type liquid crystal display device taken along line B-B' of Figure 3. Components having like functions and effects are denoted by the same reference numerals as those in Figures 1 and 2, and the description thereof is omitted.

[0080]

In the active matrix substrate in Embodiment 3, the other electrode **27** of the storage capacitor facing the electrode **25a** of the storage capacitor, which constitutes the end portion of the connecting electrode **25** connected to the drain electrode **36b** of the TFT **24** is connected to a counter electrode formed on a counter substrate via the storage capacitor common line **6** shown in Figure **14**. Each contact hole **26A** through the interlayer insulating film **38** is formed above the electrode **25a** and the other electrode **27** which is part of the storage capacitor common line **6**. In other words, the contact hole **26A** is formed above the storage capacitor line composed of a light-shading metal film.

[0081]

The above structure of the active matrix substrate of this embodiment has the following advantages.

[0082]

Since the thickness of the interlayer insulating film **38** is as large as 3 μm, for example, which is well comparable with the thickness of a liquid crystal cell of 4.5 μm, light leakage tends to occur around the contact holes **26A** due to a disturbance in the orientation of the liquid crystal molecules. If the contact holes **26A** are formed in the aperture portions of the transmission type liquid crystal display device, the contrast is lowered due to the light leakage. On the other hand, the active matrix substrate of this embodiment is free from this trouble because each contact hole **26A** is formed above the electrode **25a** and the other electrode **27** as an end portion of the storage capacitor common line **6** composed

of a light-shading metal film. In other words, as long as the contact hole 26A is formed above the storage capacitor line composed of a light-shading metal film, any light leakage which may occur due to a disturbance in the orientation of the liquid crystal will not result in lowering of the contrast. This also applies to the case where the storage capacitor is formed using a portion of the adjacent gate signal line 22 as one of electrodes thereof. In this case, the contact hole 26A is formed above the light-shading adjacent gate signal line 22 and thus lowering of the contrast can be prevented.

[0083]

In the active matrix substrate in this embodiment, the connecting electrode 25 for connecting the drain electrode 36b of the TFT 24 and the contact hole 26A is composed of the transparent conductive film 37a'. Accordingly, the aperture ratio does not become lower by forming the contact hole 26A above the storage capacitor.

[0084]

Thus, in this embodiment, since the other electrode 27 formed under the contact hole shades light, light leakage which may occur due to a disturbance in the orientation of the liquid crystal does not influence the display. The size of the contact hole 26A is not necessarily so precise, allowing the hole to be larger and smoother. As a result, the pixel electrode 21 formed on the interlayer insulating film 38 is continuous, not being interrupted by the contact hole 26A. This improves the production yield.

[0085]

(Embodiment 4)

Figure 5 is a partial sectional view of an active matrix substrate of the transmission type liquid crystal display device of Embodiment 4 according to the present invention.

[0086]

In the active matrix substrate of Embodiment 4, each contact hole **26B** is formed through the interlayer insulating film **38** above the storage capacitor common line **6**. A metal nitride layer **41** is formed on the portion of the transparent conductive film **37a'** under each contact hole **26B**.

[0087]

The above structure of the active matrix substrate of this embodiment is advantageous in the following point.

[0088]

Some troubles arise in the adhesion between the resin used for the interlayer insulating film **38** and ITO used for the transparent conductive film or metal such as Ta and Al. For example, in the cleaning process after the formation of the contact hole **26B**, a cleaning solvent tends to permeate from the contact hole **26B** into the interface between the resin and the underlying layer, causing the resin film to peel from the transparent conductive film. In order to overcome this trouble, according to the active matrix substrate in this embodiment, the metal nitride layer **41** made of TaN, AlN, and the like which has good adhesion with the resin is

formed. Accordingly, the peeling of the resin film and other troubles in the adhesion can be prevented.

[0089]

Any material can be used for the metal nitride layer 41 as long as it has good adhesion with the resin constituting the interlayer insulating film 38, the connecting electrode 37a' as the transparent conductive film, and metal such as Ta and Al. Such a material should also be electrically conductive to electrically connect the transparent conductive film 37a' and the pixel electrode 21.

[0090]

(Embodiment 5)

In Embodiment 5, a method for driving the transmission type liquid crystal display device will be described.

[0091]

In the transmission type liquid crystal display device according to the present invention, each pixel electrode overlaps the corresponding lines via the interlayer insulating film. If the pixel electrode does not overlap the corresponding lines but gaps are formed therebetween, regions where no electric field is applied are formed in the liquid crystal layer. This trouble can be avoided by overlapping the pixel electrode with the lines. The electric field also is not applied to the regions of the liquid crystal layer corresponding to the boundaries of the adjacent pixel electrodes. However, light leakage which may occur at these regions can be blocked by the existence of lines. This eliminates the

necessity of forming a black mask on a counter substrate in consideration of an error at the lamination of the active matrix substrate and the counter substrate. This improves the aperture ratio. Also, since the electric field generated at the lines can be shielded, disturbances in the orientation of the liquid crystal molecules can be minimized.

[0092]

The overlap width should be set in consideration of a variation in the actual fabrication process. For embodiment, it is preferably about 1.0 μm or more.

[0093]

Crosstalk occurs due to the capacitance between the pixel electrode and the source signal line when the pixel electrode overlaps the source signal line as described above. This lowers the display quality. In particular, in a liquid crystal panel used for a notebook type personal computer where pixels are generally arranged in a vertical stripe shape, the display is greatly influenced by the capacitance between the pixel electrode and the source signal line. This is considered to be due to the following reasons. The capacitance between the pixel electrode and the source signal line is relatively large since, in the vertical stripe arrangement, the shape of the pixel electrode is rectangular having the side along the source signal line as the major side. Also, since the display color is different between adjacent pixels, there is little correlation between signals transmitted on the adjacent source signal lines. Thus, the influence of the capacitance cannot be cancelled between the adjacent source signal lines.

[0094]

According to the transmission type liquid crystal display device of the present invention, the interlayer insulating film which is composed of an organic thin film has a small dielectric constant and can be easily thicker. Therefore, the capacitances between the pixel electrodes and the lines can be reduced, as described above. In addition to this feature, the influence of the capacitance between the pixel electrode and the source signal line can be reduced to minimize vertical crosstalk which occurs in notebook type personal computers employing the following driving method.

[0095]

The method of Embodiment 5 includes driving the transmission type liquid crystal display device by inverting the polarity of the data signal every gate signal line to reduce the capacitances between the pixel electrodes and the lines (hereinafter, this method is referred to as 1H inversion driving).

[0096]

Figure 6 shows the influences of the capacitance between the pixel electrode and the source signal line upon the charging rate of the pixel in the cases of the 1H inversion driving (Figure 7a) and a driving method where the polarity of the data signal is inverted every field (hereinafter, this method is referred to as field inversion driving) (Figure 7b).

[0097]

Figure 6 shows the ratio of the effective value of the voltage applied to the liquid crystal in the gray

scale display portion when the gray scale is uniformly displayed to that when a black window pattern is displayed in the gray scale display at a vertical occupation of 33%. The X axis represents the capacitance ratio which is proportional to the variation in the voltage of the pixel electrode caused by the capacitance between the pixel electrode and the source signal line, which is represented by expression (1) below:

[0098]

$$\text{Capacitance ratio} = C_{sd} / (C_{sd} + C_{ls} + C_s) \qquad \ldots(1)$$

wherein C_{sd} denotes the capacitance value between the pixel electrode and the source signal line, C_{ls} denotes the capacitance value of the liquid crystal portion corresponding to each pixel at the gray scale display, and C_s denotes the capacitance value of the storage capacitor of each pixel. The gray scale display refers to the display obtained when the transmittance is 50%.

[0099]

As is observed from Figure 6, in the 1H inversion driving of Embodiment 5, the influence of the capacitance between the pixel electrode and the source signal line upon the effective voltage actually applied to the liquid crystal layer can be reduced to one-fifth to one-tenth of that obtained in the field inversion driving when the capacitance value is the same. This is because, in the 1H inversion driving, the polarity of the data signal is inverted at intervals sufficiently shorter than the period of one field during one field. This results in cancelling the influences of the positive signal and the negative signal on the display with each other.

[0100]

A display test was conducted using a VGA panel with a diagonal of 26 cm. From this test, it was observed that crosstalk was eminent when the charging rate difference was 0.6% or more, degrading the display quality. This is shown by the dotted curve in Figure 6. From the curve in Figure 6, it is found that the capacitance ratio should be 10% or less in order to obtain the charging rate difference of 0.6% or less.

[0101]

Figure 8 shows the relationships between the overlap amount between the pixel electrode and the source signal line and the capacitance between the pixel electrode and the source signal line when the thickness of the interlayer insulating film is used as a parameter. The VGA panel with a diagonal of 26 cm was also used in this test. In the test, the acrylic photosensitive resin (dielectric constant: 3.4) used in Embodiment 1 was used as the interlayer insulating film. In consideration of the processing precision, the overlap width between the pixel electrode and the source signal line should be at least 1 μm. From Figures 6 and 8, it is found that the thickness of the interlayer insulating film should be 2.0 μm or more to satisfy the overlap width of 1 μm and the charging rate difference of 0.6% or less.

[0102]

Thus, according to the 1H inversion driving of this embodiment, a good display free from vertical crosstalk can be obtained without inverting the polarity of the signal on the adjacent source signal lines when the pixel electrode overlaps the source signal line.

This method is therefore applicable to notebook type personal computers.

[0103]

(Embodiment 6)

In Embodiment 6, another method for driving the transmission type liquid crystal display device will be described, where the polarity of the voltage applied to the liquid crystal is inverted every gate signal line, and simultaneously the signal applied to the counter electrode is driven by alternate current in synchronization with the inversion of the polarity of the source signal.

[0104]

This driving of the counter electrode can minimize the amplitude of the source signal.

[0105]

Figure 6 also shows the curve obtained when the counter electrode is AC driven with an amplitude of 5 V. From Figure 6, it is observed that, since the 1H inversion driving is employed, the charging rate difference is sufficiently small compared with the case of the field inversion driving, though it is larger by about 10 percent than that obtained in the previous embodiment due to the AC driving of the counter electrode in this embodiment. As a result, a good display without vertical crosstalk can be realized in the driving method of this embodiment.

[0106]

(Embodiment 7)

In the transmission type liquid crystal display device of Embodiment 7, each flat pixel electrode overlaps corresponding lines to improve the aperture ratio of the liquid crystal display, minimize disturbances in the orientation of the liquid crystal, and simplify the fabrication process. Also, the influence of the capacitances between the pixel electrode and the lines appearing on the display, such as crosstalk, is minimized thereby achieving a good display. In this embodiment, an interlayer insulating film with high transparency can be obtained. After the light exposure and development of the interlayer insulating film, the entire substrate is exposed to light to react the remaining unnecessary photosensitive agent contained in the photosensitive transparent acrylic resin.

[0107]

Figure 9 is a plan view of a one-pixel portion of an active matrix substrate of the transmission type liquid crystal display device of Embodiment 7.

[0108]

Referring to Figure 9, the active matrix substrate includes a plurality of pixel electrodes 51 arranged in a matrix. Gate signal lines 52 and source signal lines 53 run along the peripheries of the pixel electrodes 51 to cross each other. The peripheries of each pixel electrode 51 overlap the gate signal lines 52 and the source signal lines 53. A TFT 54 as a switching element connected to the corresponding pixel electrode 51 is formed at a crossing of the gate signal line 52 and the source signal line 53. A gate electrode of the TFT 54 is connected to the gate signal line 52 so that a

gate signal is input into the gate electrode to control the driving of the TFT 54. A source electrode of the TFT 54 is connected to the source signal line 53 so that a data signal can be input into the source electrode of the TFT 54. A drain electrode of the TFT 54 is connected to the corresponding pixel electrode 51 via a connecting electrode 55 and a contact hole 56. The drain electrode is also connected to one electrode 55a of a storage capacitor via the connecting electrode 55. The other electrode 57 of the storage capacitor is connected to a common line.

[0109]

Figure 10 is a sectional view of the active matrix substrate of the transmission type liquid crystal display device, taken along line C-C' of Figure 9.

[0110]

Referring to Figure 10, a gate electrode 62 connected to the gate signal line 52 shown in Figure 9 is formed on a transparent insulating substrate 61. A gate insulating film 63 is formed covering the gate electrode 62. A semiconductor layer 64 is formed on the gate insulating film so as to overlap the gate electrode 62, and a channel protection layer 65 is formed on the center of the semiconductor layer 64. n^+-Si layers as a source electrode 66a and a drain electrode 66b are formed covering the end portions of the channel protection layer 65 and portions of the semiconductor layer 64, so that they are separated from each other at the top of the channel protection layer 65. A transparent conductive film 67a and a metal layer 67b which are to be the double-layer source signal line 53 are formed to overlap

the source electrode **66a** as one of the n^+-Si layers. A transparent conductive film **67a'** and a metal layer **67b'** are formed to overlap the drain electrode **66b** as the other n^+-Si layer. The transparent conductive film **67a'** extends to connect the drain electrode **66b** and the pixel electrode **51** and also serves as the connecting electrode **55** which is connected to the electrode **55a**. An interlayer insulating film **68** is formed covering the TFT **54**, the gate signal line **52**, the source signal line **53**, and the connecting electrode **55**. The interlayer insulating film **68** is made of a high-transparency acrylic resin (photosensitive transparent acrylic resin) which dissolves in a developing solution when exposed to light.

[0111]

A transparent conductive film is formed on the interlayer insulating film **68** to constitute the pixel electrode **51**, which is connected to the drain electrode **66b** of the TFT **54** via the contact hole **66** formed through the interlayer insulating film **68** and the transparent conductive film **67d'** which is the connecting electrode **55**.

[0112]

The active matrix substrate in Embodiment 7 with the above structure is fabricated as follows.

[0113]

First, the gate electrode **62** made of Ta, Al, Mo, W, Cr, and the like, the gate insulating film **63** made of SiN_x, SiO_2, Ta_2O_5, and the like, the semiconductor layer (i-SI) **64**, the channel protection layer **65** made of SiN_x, Ta_2O_5, and the like, the n^+-Si layers as the source elec-

trode 66a and the drain electrode 66b are sequentially formed in this order on the transparent insulating substrate 61 such as a glass substrate. Thereafter, the transparent conductive films 67a and 67a' and the metal layers 67b and 67b' made of Ta, Al, MoW, Cr, and the like constituting the source signal line 53 and the connecting electrode 55 are sequentially formed by sputtering and are patterned into a predetermined shape. In Embodiment 7, as in the previous embodiments, the source signal line 53 is of the double-layer structure composed of the transparent conductive film 67a, 67a' made of ITO and the metal film 67b, 67b'. With this structure, if part of the metal layer 67b, 67b' is defective, the source signal line 53 can remain electrically conductive through the ITO film, so that the occurrences of disconnection of the source signal line 53 can be reduced.

[0114]

A photosensitive acrylic resin is applied to the resultant structure to a thickness of 2 μm, for example, by spin coating to form the interlayer insulating film 68. The resultant resin layer is exposed to light according to a predetermined pattern and developed with an alkaline solution. Only the portions exposed to light are etched with the alkaline solution, which forms the contact holes 56 through the interlayer insulating film 68.

[0115]

Subsequently, a transparent conductive film is formed over the interlayer insulating film 68 and the contact holes 56 by sputtering and is patterned to form the pixel electrodes 51. Thus, each pixel electrode 51

is connected to the transparent conductive film 67a' which is in contact with the drain electrode 66b of the TFT 54 via the contact hole 56 formed through the interlayer insulating film 68. In this way, the active matrix substrate in Embodiment 7 is fabricated.

[0116]

The interlayer insulating film 68 of Embodiment 7 is made of a photosensitive transparent acrylic resin with high transparency which dissolves in a developing solution after exposure to light. The photosensitive transparent acrylic resin includes a polymer of methacrylic acid and glycidyl methacrylate as a base polymer. Hereinbelow, the formation of the interlayer insulating film 68 using the photosensitive transparent acrylic resin with high transparency will be described in more detail.

[0117]

In the formation of the interlayer insulating film 68, first, a solution containing the photosensitive transparent acrylic material is applied to the substrate by spin coating, followed by a normal photo-patterning process including prebaking, pattern exposure, alkaline development, and cleaning with pure water in this order.

[0118]

Specifically, the interlayer insulating film 68 with a thickness of 3 μm is formed by applying a solution containing the photosensitive transparent acrylic resin to the resultant substrate by spin coating. The thickness should be at least 1.5 μm. More specifically, the acrylic resin with a viscosity of 29.0 cp is applied at

a spin rotation of 900 to 1100 rpm. This makes it possible to obtain flat pixel electrodes without steps unlike in the conventional method, minimizing disturbances in the orientation of liquid crystal and improving the resultant display quality. Subsequently, the resultant substrate is heated to about 100°C to dry a solvent of the photosensitive transparent acrylic resin (ethyl lactate, propylene glycol monomethyl ether acetate, etc.). The resultant photosensitive acrylic resin is exposed to light according to a predetermined pattern and developed with an alkaline solution (tetramethyl ammonium hydroxyoxide, abbreviated to "TMAH"). The portions of the substrate exposed to light are etched with the alkaline solution, forming the contact holes 56 through the interlayer insulating film 68. The concentration of the developing solution is preferably in the range of 0.1 to 1.0 mol% (in the case of TMAH). When the concentration exceeds 1.0 mol%, the portions of the photosensitive transparent acrylic resin which are not exposed to light are also largely etched, making it difficult to control the thickness of the photosensitive transparent acrylic resin. When the concentration of the developing solution is as high as 2.4%, altered substances from the acrylic resin are left in the etched portions as residues, causing contact failure. When the concentration is less than 0.1 mol%, the concentration largely varies in an developing apparatus where the developing solution is circulated for repeated use. This makes it difficult to control the concentration.

[0119]

Thereafter, the developing solution left on the substrate surface is washed away with pure water. As

described above, the interlayer insulating film can be formed by spin coating. Accordingly, the thickness of the film which may be several micrometers can be made uniform easily by appropriately selecting the rotation rate of the spin coater and the viscosity of the photosensitive transparent acrylic resin. The contact hole can be made into a smooth tapered shape by appropriately selecting the amount of light exposure during the pattern exposure, the concentration of the developing solution, and the developing time.

[0120]

The resin may appear colored after the development depending on the type and amount of the photosensitive agent (e.g., naphthoquinone diazide photosensitive agents and naphthoquinone diazide positive-type photosensitive agents) contained in the photosensitive transparent acrylic resin. To avoid this problem, the entire substrate is exposed to light to allow the remaining unnecessary colored photosensitive agent contained in the resin to completely react, so as to eliminate light absorption in the visible region and thereby to make the acrylic resin transparent. Examples of the photosensitive agent include naphthoxy diazide positive-type photosensitive agents and naphthoquinone diazide photosensitive agents. Figure 11 shows the variation in the light transmittance of the surface of the acrylic resin with a thickness of 3 μm before and after being exposed to light such as ultraviolet light, depending on the wavelength (nm) of the transmitted light. As is observed from Figure 11, when the resin has not been exposed to light, the transmittance of the resin is 65% for transmitted light with a wavelength of 400 nm. After

the resin is exposed to light, the transmittance is improved to 90% or more. In this case, the substrate was irradiated with light from the front side thereof. This light exposure step can be shortened by irradiating the substrate with light from both the front side and the back side. This improves the throughput of the process.

[0121]

Finally, the resultant substrate is heated to cure the resin by crosslinking. More specifically, the substrate is placed on a hot plate or in a clean oven and heated to about 200°C to cure the resin.

[0122]

Thus, by using the photosensitive transparent resin, the interlayer insulating film 68 and the contact holes 56 formed through the interlayer insulating film 68 for connecting the pixel electrodes and the drain electrodes of the switching elements can be formed only by the photo-patterning without the conventional etching and resist-removing steps. This simplifies the fabrication process. The thickness of the photosensitive transparent acrylic resin may be any desired value in the range of 0.05 to 10 μm (3 μm in Embodiment 7; note that the light transmittance lowers and the coloring is more prominent as the thickness becomes larger) and can be made uniform by appropriately selecting the viscosity of the resin solution and the rotation of the spin coater during spin coating.

[0123]

Thereafter, ITO is deposited on the photosensitive transparent acrylic resin to a thickness of 500 to

1500 angstrom by sputtering and is patterned to form the pixel electrodes 51. The ITO film as each pixel electrode 51 having a thickness of 500 angstrom or more effectively prevents an agent (dimethyl sulfoxide, etc.) used as a removing solution from permeating from gaps of the surface of the ITO film into the resin and the resin from expanding due to the permeation of the agent. The active matrix substrate in Embodiment 7 is thus fabricated.

[0124]

Thus, in Embodiment 7, as in the previous embodiments, with the existence of the interlayer insulating film 68, all the portions of the display panel other than the source and gate signal line portions can be used as pixel aperture portions. The resultant liquid crystal display device is bright with high transmittance and a large aperture ratio.

[0125]

Moreover, with the existence of the interlayer insulating film 68, the pixel electrodes can be made flat without being influenced by steps formed by the underlying lines and switching elements. This prevents the occurrence of disconnection conventionally found at the steps on the drain sides of the pixel electrodes, and thereby reduces the number of defective pixels. Disturbances in the orientation of liquid crystal molecules caused by the steps can also be prevented. Furthermore, since the source signal lines 53 and the pixel electrodes 51 are isolated from each other with the interlayer insulating film 68 therebetween, the number of defective pixels conventionally caused by the electrical

leakage between the source signal lines 53 and the pixel electrodes 51 can be reduced.

[0126]

Further, in Embodiment 7, the interlayer insulating film 68 can be formed only by the resin formation step, instead of the film formation step, the pattern formation step with a photoresist, the etching step, the resist removing step, and the cleaning step conventionally required. This simplifies the fabrication process.

[0127]

(Embodiment 8)

In Embodiment 8, the method for improving the adhesion between the interlayer insulating film 68 and the underlying films described in Embodiment 7 will be described.

[0128]

The adhesion of the photosensitive transparent acrylic resin as the interlayer insulating film 68 with the underlying films may be inferior depending on the materials of the underlying films. In such a case, according to the method of this embodiment, the surfaces of the underlying films, i.e., the gate insulating film 63, the channel protection film 65, the source electrode 66a, the drain electrode 66b, the transparent conductive films 67a and 67a', and the metal films 67b and 67b' are exposed to ultraviolet light from an M-type mercury lamp (860 W) in an oxygen atmosphere before the application of the photosensitive transparent acrylic resin, so as to roughen the surfaces. The interlayer insulating film 68 made of the photosensitive transparent

acrylic resin is then formed on the roughened surfaces of the underlying films. The subsequent steps are the same as those described in Embodiment 7. By this method, the adhesion between the photosensitive transparent acrylic resin and the surface-roughened underlying films improves. This overcomes the conventional problem of the film peeling at the interface between the interlayer insulating film 68 made of the photosensitive transparent acrylic resin and the underlying films arising when an agent such as a mixture of hydrochloric acid and iron chloride for etching ITO permeates into the interface.

[0129]

Thus, by irradiating the substrate surface before the formation of the interlayer insulating film 68 with ultraviolet light, the adhesion between the interlayer insulating film 68 and the underlying films improves. The resultant device can be stable despite further processing during the fabrication process.

[0130]

(Embodiment 9)

In Embodiment 9, the method for improving the adhesion between the interlayer insulating film 68 and the pixel electrode material formed thereon described in Embodiment 7 will be described.

[0131]

After the formation of the interlayer insulating film 68 made of the photosensitive transparent acrylic resin in Embodiment 7, the surface portion of the interlayer insulating film 68 with a thickness of 1000 to 5000 angstrom is ashed in an oxygen plasma atmosphere

using a dry etching apparatus. More specifically, the surface of the acrylic resin is ashed in the oxygen plasma atmosphere using a parallel plane type plasma etching apparatus under the conditions of a RF power of about 1.2 KW, a pressure of about 800 m Torr, an oxygen flow rate of about 300 sccm, a temperature of 70°C, and a RF applying time of about 120 seconds. By this process, water and carbon dioxide are released from the surface by oxidation decomposition of an organic substance in the oxygen plasma, and thus the surface is roughened.

[0132]

Thereafter, ITO is deposited on the roughened photosensitive transparent acrylic resin to a thickness of about 500 to about 1500 angstrom by sputtering and patterned to form the pixel electrodes 51. The active matrix substrate is thus fabricated. By this ashing, the adhesion between the pixel electrodes 68 and the underlying roughened interlayer insulating film 68 made of the photosensitive transparent acrylic resin greatly improves. No delamination at the interface thereof was caused by an application of ultrasound for cleaning the substrate. The above effect was not obtained when the thickness of the ashed surface portion of the acrylic resin was less than 1000 angstrom. When it exceeds 5000 angstrom, the decrease in the thickness of the photosensitive transparent acrylic resin is so large that the variation in the thickness of the resultant acrylic resin increases, causing display troubles. The improvement in the adhesion is obtained by using any type of the dry etching apparatus including a barrel type and a RIE type.

[0133]

Thus, by ashing the surface portion of the interlayer insulating film 68 in the oxygen plasma atmosphere before the formation of the pixel electrodes, the adhesion between the interlayer insulating film 68 and the pixel electrode material formed thereon improves. The resultant device can be stable against further processing during the fabrication process.

[0134]

In Embodiments 1 to 9 above, each pixel electrode overlaps the corresponding lines to improve the aperture ratio of the liquid crystal display, to minimize disturbances in the orientation of the liquid crystal, and to simplify the fabrication process. Also, the influence of the capacitances between the pixel electrode and the lines appearing on the display, such as crosstalk, is minimized to achieve a good display. In addition to these features, a wide viewing angle can be obtained.

[0135]

The wide viewing angle can be obtained due to the following reasons; that is, the orientation of the liquid crystal is not disturbed since the surfaces of the pixel electrodes are flat; no disclination line is generated due to the electric field generated at the lines; and the contrast is large (1:300 or more for a 10.4-inch SVGA). As a result, the retardation value, i.e., the refractive index anisotropy of liquid crystal (Δn) $\times$ cell thickness (d), can be reduced. This reduction of the retardation is obtained mainly by reducing the cell thickness d according to the present invention. In general, as the

value of $\Delta n \times d$ decreases, the viewing angle increases but the contrast decreases. According to the present invention, however, the size of the pixel electrodes is made large by eliminating the margins conventionally provided between the pixel electrodes and the corresponding lines. For example, the aperture ratio increased by about 20 points from 65% to 86%, and the brightness also increased by more than 1.5 times. Since the contrast significantly improves, it is possible to widen the viewing angle by decreasing $\Delta n \times d$ and thus to compensate the conventional decrease of the contrast. The wide viewing angle can be thus achieved, and as a result, high image quality without inversion when viewed from a side can be obtained. This effect is especially eminent for TN type LCDs.

[0136]

Embodiments 3 and 4 above described the transmission type liquid crystal display device where one electrode of the storage capacitor is connected to the counter electrode via the storage capacitor common line. The same effects obtained by the above structure can also be obtained by using the gate signal line 22 of the adjacent pixel as the electrode. Figures 12 and 13 show the latter structure. This type of liquid crystal display device is called a C_s-on-gate type, where each pixel electrode 21 overlaps the immediately before or next gate signal line 22 to form a storage capacitor C_s. In this case, the pixel electrode 21 preferably overlaps a larger portion of the immediately before or next gate signal line while it overlaps a smaller portion of the corresponding gate signal line.

[0137]

In Embodiments 1 to 9, the photosensitive transparent acrylic resin with high transparency is applied by spin coating and patterned to form the interlayer insulating film, and the contact holes are formed through the interlayer insulating film to reach the connecting electrode. The application of the photosensitive transparent acrylic resin can also be conducted by methods other than the spin coating, such as roll coating (a method where a substrate is allowed to pass through between a roll with an uneven surface and a belt with the surface of the substrate to be subjected to the coating facing the roll) and slot coating (a method where a substrate is allowed to pass under an ejection slot, and the thickness of the resultant coating is determined by the width of the ejection slot). The effects of the present invention can also be obtained by these methods.

[0138]

In Embodiments 7 and 8, among the i line (wavelength: 295 nm), the h line (wavelength: 310 nm), and the g line (wavelength: 340 nm) of ultraviolet light generally used for the light exposure process, the i line (wavelength: 295 nm) having the shortest wavelength is used. This shortens the light irradiation time, and is highly effective in decoloring in Embodiment 7 and in roughening the surface in Embodiment 8.

[0139]

[Effect of the Invention]

Thus, according to the present invention, with the existence of the interlayer insulating film, each pixel electrode can be formed to overlap the correspond-

ing lines. This improves the aperture ratio and minimizes disturbances in the orientation of the liquid crystal molecules. Since the interlayer insulating film is composed of an organic thin film, the dielectric constant thereof is smaller and the thickness thereof can be easily larger, compared with an inorganic thin film. Thus, the capacitances between the pixel electrode and the lines can be reduced. As a result, vertical crosstalk caused by the capacitance between the pixel electrode and the source signal line can be reduced, and the feedthrough of the write voltage to the pixels caused by the capacitance between the pixel electrode and the gate signal line, as well as the variation in the fabrication process, can be reduced.

[0140]

In the formation of the interlayer insulating film, the photosensitive organic material such as an acrylic resin is applied to the substrate by a coating method and patterned by light exposure and development to obtain an organic thin film with a thickness of several micrometers with high productivity. This makes it possible to fabricate the transmission type liquid crystal display device with a high aperture ratio without largely increasing production cost. The transmission type liquid crystal display device with a high aperture ratio can also be obtained by forming the organic thin film by deposition, forming a photoresist on the organic thin film, and patterning the organic thin film in an etching process. In the case where the resin used for the interlayer insulating film is colored, the resin can be made transparent by optically or chemically decoloring the resin after the patterning. As a result, a transmis-

sion type liquid crystal display device with a good color display can be obtained.

[0141]

The connecting electrode for connecting the other electrode of the TFT and the pixel electrode is formed using the transparent conductive film. This further improves the aperture ratio. The transparent conductive film can be formed simultaneously with the source signal line which is of a double-layer structure including the transparent conductive film. With the double-layer structure, disconnection at the source signal line can be prevented.

[0142]

Each contact hole is formed through the interlayer insulating film above the storage capacitor line or the scanning line. This improves the contrast ratio because light leakage which may be generated due to a disturbance in the orientation of the liquid crystal can be blocked by the storage capacitor portion.

[0143]

The metal nitride layer may be formed under each contact hole formed through the interlayer insulating film. This improves the adhesion between the interlayer insulating film and the underlying film. Thus, the resultant liquid crystal display device is stable against further processing in the production process.

[0144]

Each pixel electrode may overlap the corresponding source signal line by 1 μm or more. With this

overlap, the aperture ratio, as well as the processing precision, improves. By having the thickness of the interlayer insulating film of 1.5 μm or more (preferably, 2.0 μm or more), the capacitance between each pixel electrode and the corresponding source signal line can be sufficiently small even when the pixel electrode overlaps the source signal line by 1 μm or more. As a result, a good display can be provided.

[0145]

The vertical crosstalk is further reduced by decreasing the capacitance ratio represented by expression (1) above to 10% or less, since the capacitance between the pixel electrode and the source signal line is sufficiently reduced.

[0146]

The polarity of the data signal supplied from the source signal line may be inverted every gate signal line. This further reduces the generation of vertical crosstalk.

[0147]

The effects of the present invention can also be obtained for the active matrix substrate where the pixel electrodes are arranged in a vertical stripe shape and each pixel electrode is of a rectangular shape with the side thereof parallel to the source signal line being longer than the side thereof parallel to the gate signal line, as well as the case where each pixel electrode is of a square shape. This makes it possible to obtain a large-scale liquid crystal display device with a high aperture ratio free from vertical crosstalk for notebook

type personal computers and the like.

[0148]

Since the interlayer insulating film according to the present invention is comparatively thick and can be made flat, conventional troubles caused by steps formed by the underlying lines and the like, such as disconnection on the drain side of the pixel electrode, are overcome. Disturbances in the orientation of the liquid crystal is also prevented. The pixel electrodes and the lines are isolated by the interlayer insulating film formed therebetween. This greatly reduces the number of defective pixels due to electrical leakage between the pixel electrodes and the lines, thereby increasing production yield and reducing production cost. Moreover, according to the present invention, the interlayer insulating film can be formed only by the resin formation step, instead of the film formation step, the pattern formation step with a photoresist, the etching step, the resist removing step, and the cleaning step conventionally required. This simplifies the fabrication process and reduces production cost.

[0149]

The entire substrate may be exposed to light to allow the remaining unnecessary photosensitive agent contained in the photosensitive transparent acrylic resin to completely react after the light exposure and development of the interlayer insulating film. With this process, an interlayer insulating film with higher transparency can be obtained.

[0150]

The surface of the substrate before the formation of the interlayer insulating film may be irradiated with ultraviolet light. This improves the adhesion between the interlayer insulating film and the underlying film. Thus, the resultant liquid crystal display device can be stable against further processing in the production process.

[0151]

The surface of the interlayer insulating film may be ashed in an oxygen plasma atmosphere before the formation of the film of pixel electrode material. This improves the adhesion of the interlayer insulating film and the film of the pixel electrode material formed thereon. Thus, the resultant liquid crystal display device can be stable against further processing in the production process.

[0152]

The pixel electrodes with a thickness of 500 angstrom or more can effectively prevent an agent used as a removing solution from permeating from gaps of the film surface into the resin and the resin from expanding due to the permeation of the agent.

[0153]

As the aperture ratio of the display improves, the brightness thereof also improves. Accordingly, the viewing angle can be widened by reducing the retardation without degrading the contrast. This makes it possible to obtain a significantly wide viewing angle.

[Brief Description of the Drawings]

[Figure 1]

A plan view of a one-pixel portion of an active matrix substrate of a transmission type liquid crystal display device of Embodiment 1 according to the present invention.

[Figure 2]

A sectional view of the active matrix substrate of the transmission type liquid crystal display device, taken along line A-A' of Figure 1.

[Figure 3]

A plan view of a one-pixel portion of an active matrix substrate of a transmission type liquid crystal display device of Embodiment 3 according to the present invention.

[Figure 4]

A sectional view of the active matrix substrate of the transmission type liquid crystal display device, taken along line B-B' of Figure 3.

[Figure 5]

A partial sectional view of an active matrix substrate of a transmission type liquid crystal display device of Embodiment 4 according to the present invention.

[Figure 6]

A graph illustrating the relationship between the liquid crystal charging rate difference and the capacitance ratio for transmission type liquid crystal display devices of Embodiments 5 and 6 according to the present

invention and a conventional liquid crystal display device.

[Figure 7]

A view illustrating waveforms of data signals in the cases of 1H inversion driving in Embodiments 5 and 6 according to the present invention and conventional field inversion driving, respectively.

[Figure 8]

A graph illustrating the relationship between the liquid crystal capacitance ratio and the overlap width for the transmission type liquid crystal display device of Embodiment 5 according to the present invention.

[Figure 9]

A plan view of a one-pixel portion of an active matrix substrate of a transmission type liquid crystal display device of Embodiment 7 according to the present invention.

[Figure 10]

A sectional view of the active matrix substrate of the transmission type liquid crystal display device, taken along line C-C' of Figure 9.

[Figure 11]

A graph illustrating the variation in the transmittance before and after light exposure of an acrylic resin, depending on the wavelength (nm) of transmitted light for the transmission type liquid crystal display device of Embodiment 7 according to the present invention.

[Figure 12]

A circuit diagram of a C_s-on-gate type liquid crystal display device.

[Figure 13]

A plan view of a one-pixel portion of an active matrix substrate obtained by applying the structure of Embodiment 3 according to the present invention to the liquid crystal display device shown in Figure 12.

[Figure 14]

A plan view of a one-pixel portion of an active matrix substrate of a conventional liquid crystal display device.

[Figure 15]

A sectional view of a TFT portion of the active matrix substrate of the conventional liquid crystal display device.

[Description of Reference Numerals]

6 Storage capacitor common line
21, 51 Pixel electrodes
22, 52 Gate signal lines
23, 53 Source signal lines
24, 54 TFTs
25, 55 Connecting electrodes
26, 26A, 26B, 56 Contact holes
31, 61 Transparent insulating substrates
32, 62 Gate electrodes
36a, 66a Source electrodes
36b, 66b Drain electrodes
37a, 37a', 67a, 67a' Transparent conductive

films

37b, 37b', 67b, 67b' Metal layers

38, 68 Interlayer insulating films

41 Titanium nitride layer

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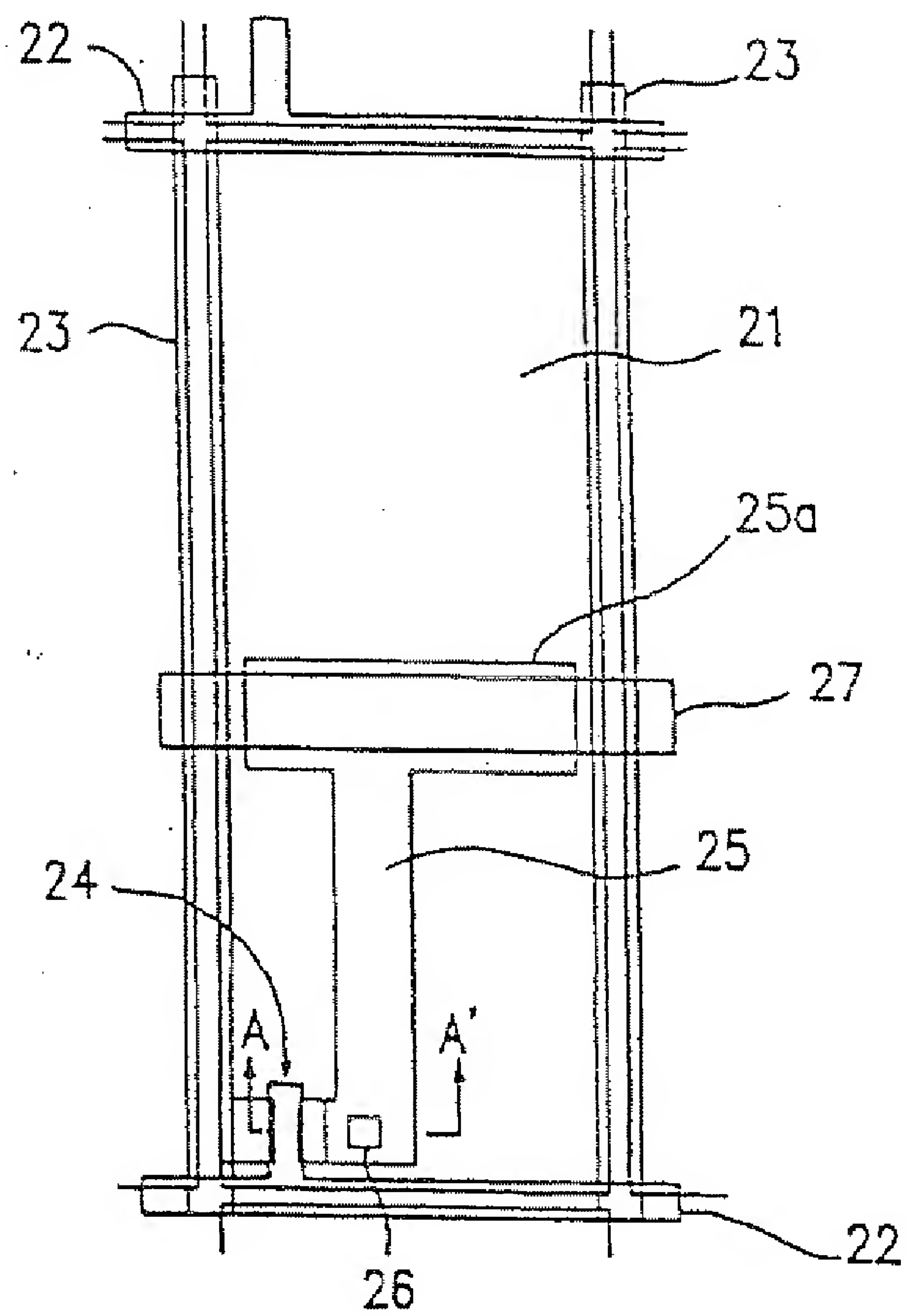
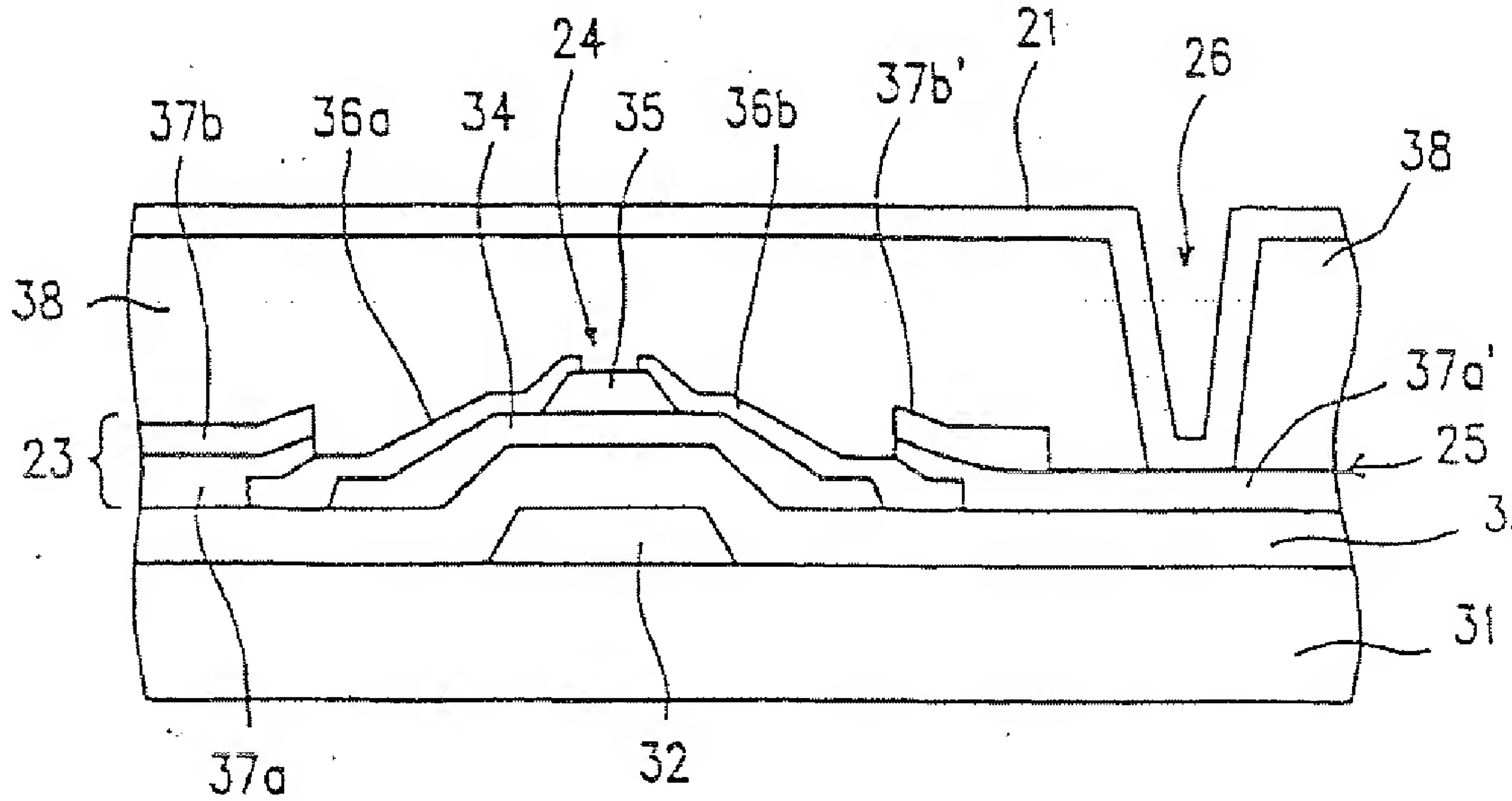
[Name of the Document] DRAWINGS

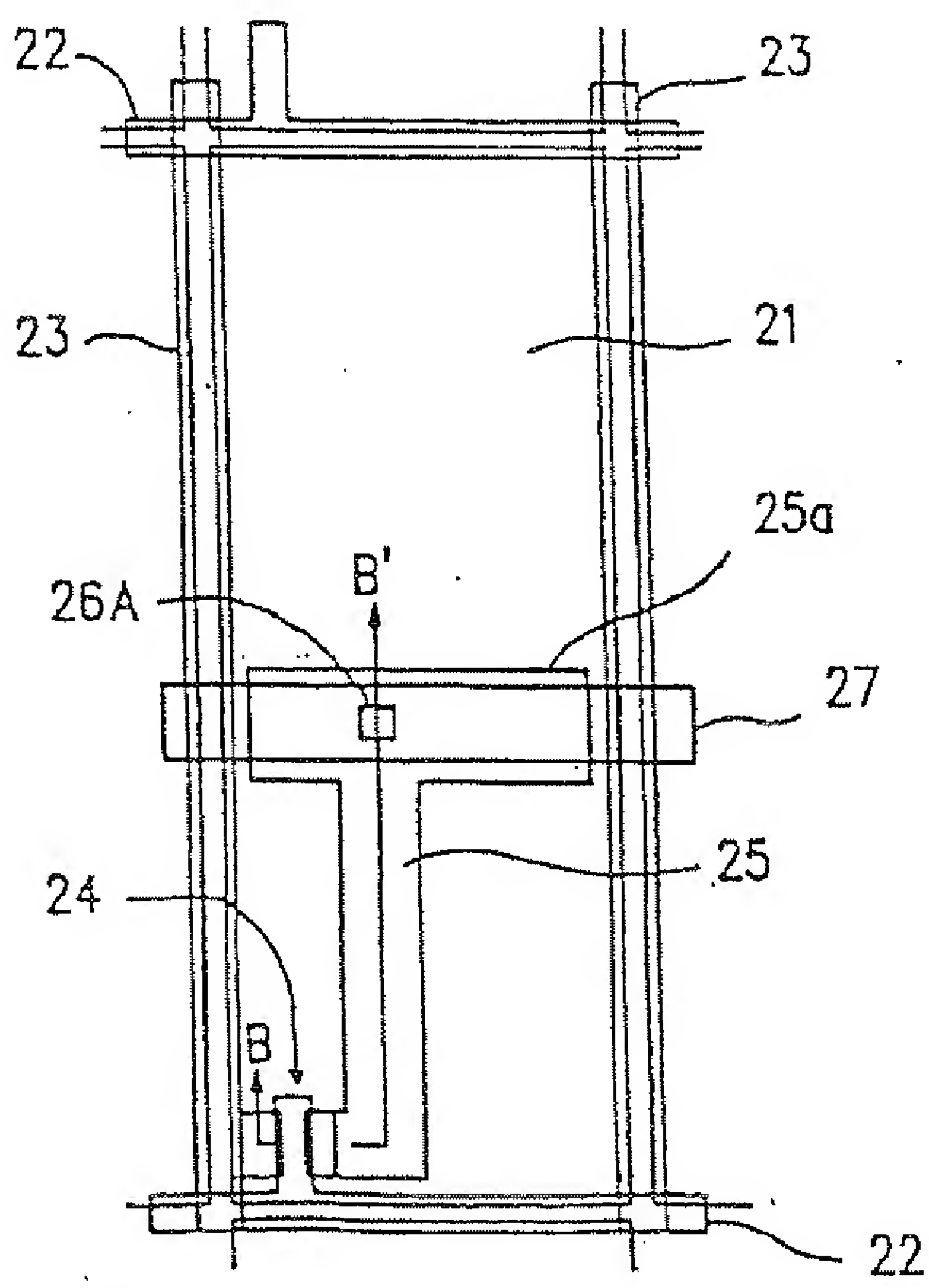
[Fig. 1]



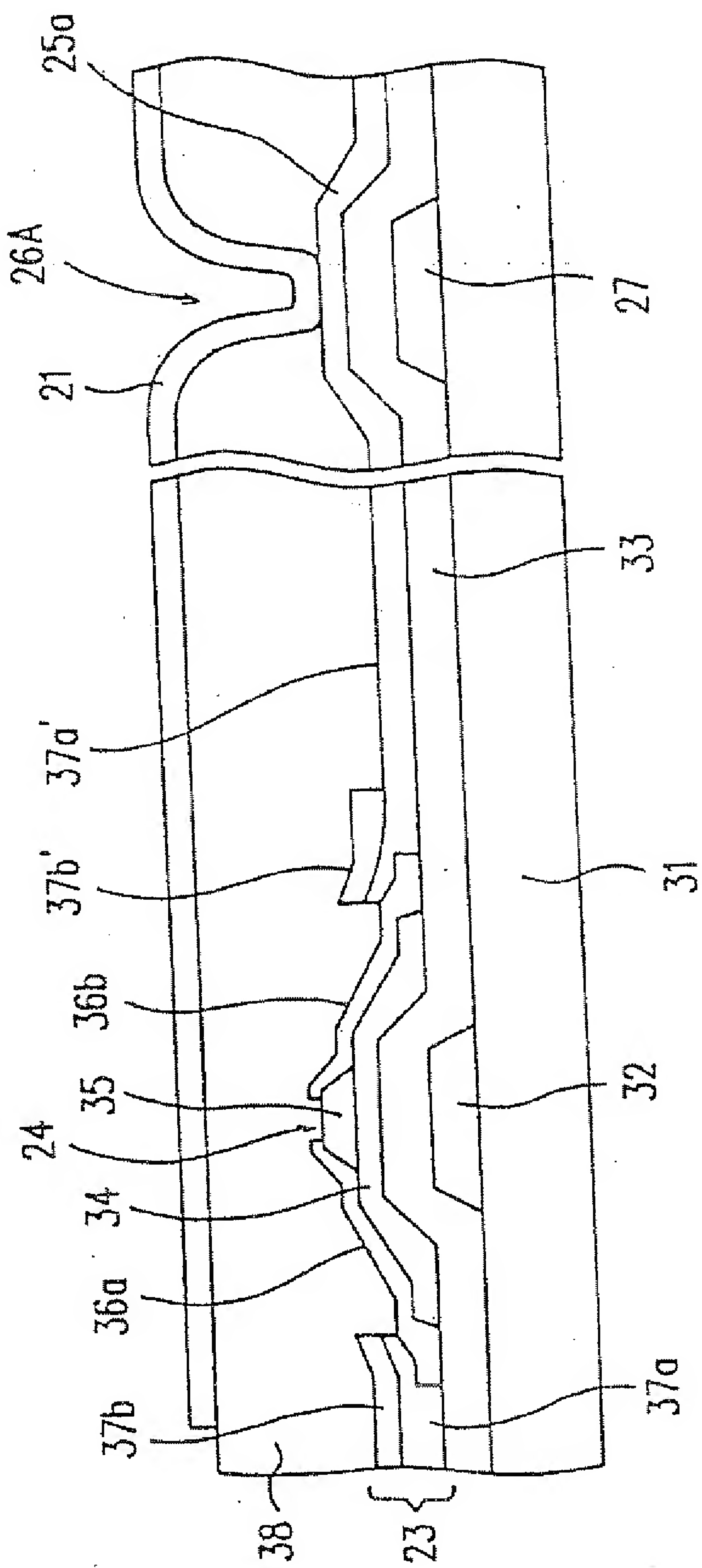
[Fig. 2]


24
21
26
37b
36a
34
35
36b
37b'
38
38
37a'
23
25
33
31
37a
32

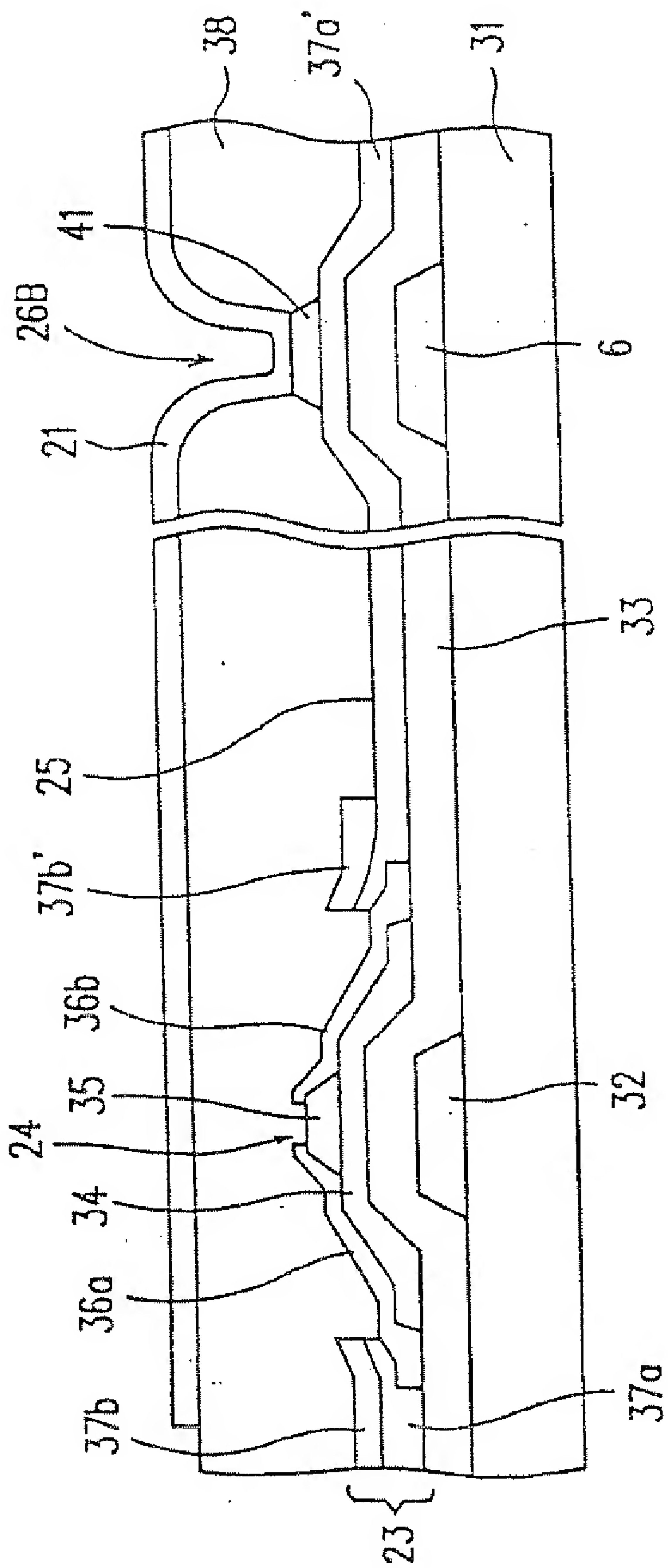
[Fig. 3]


22
23
23
21
25a
B'
26A
27
25
24
B
22

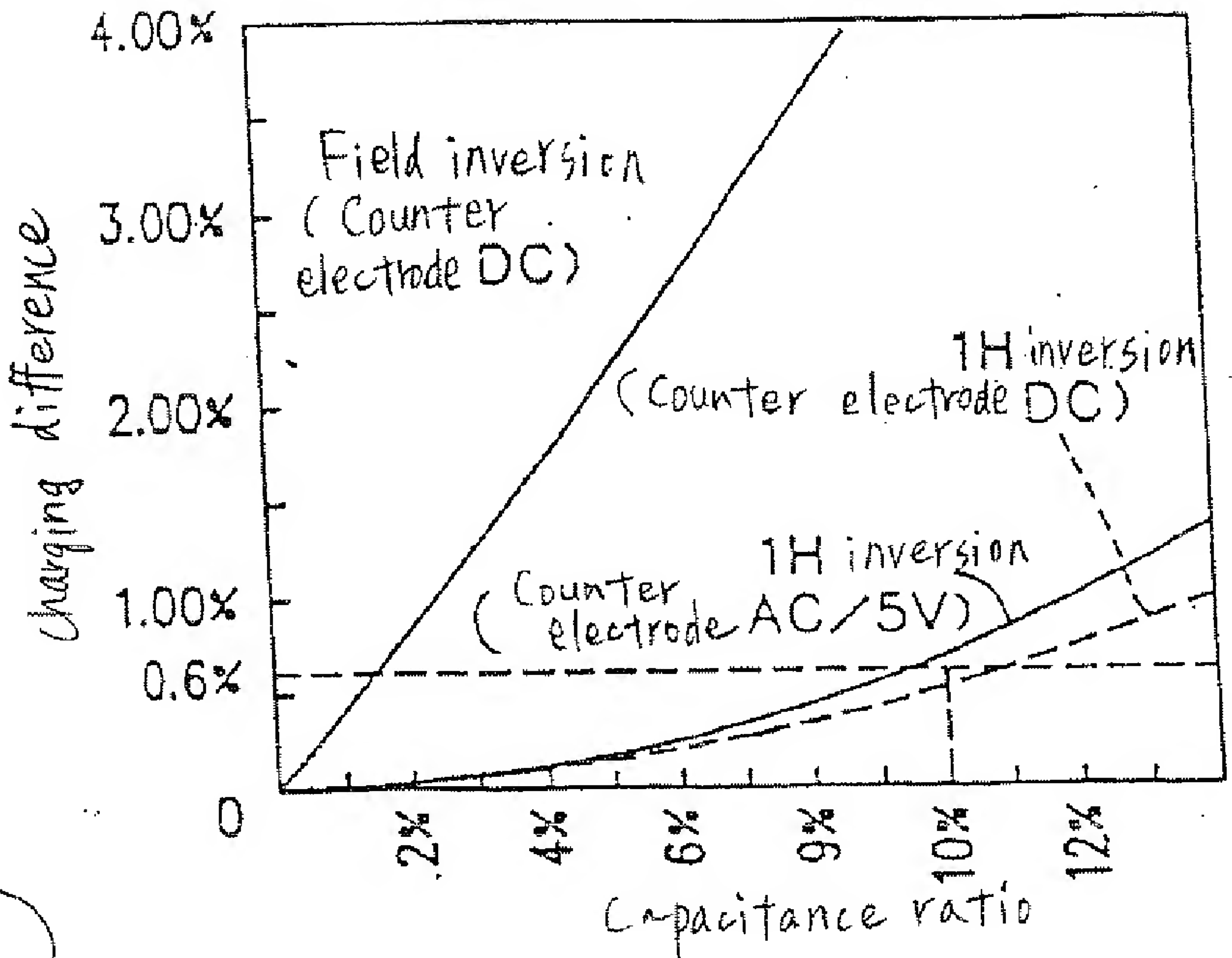
[Fig. 4]



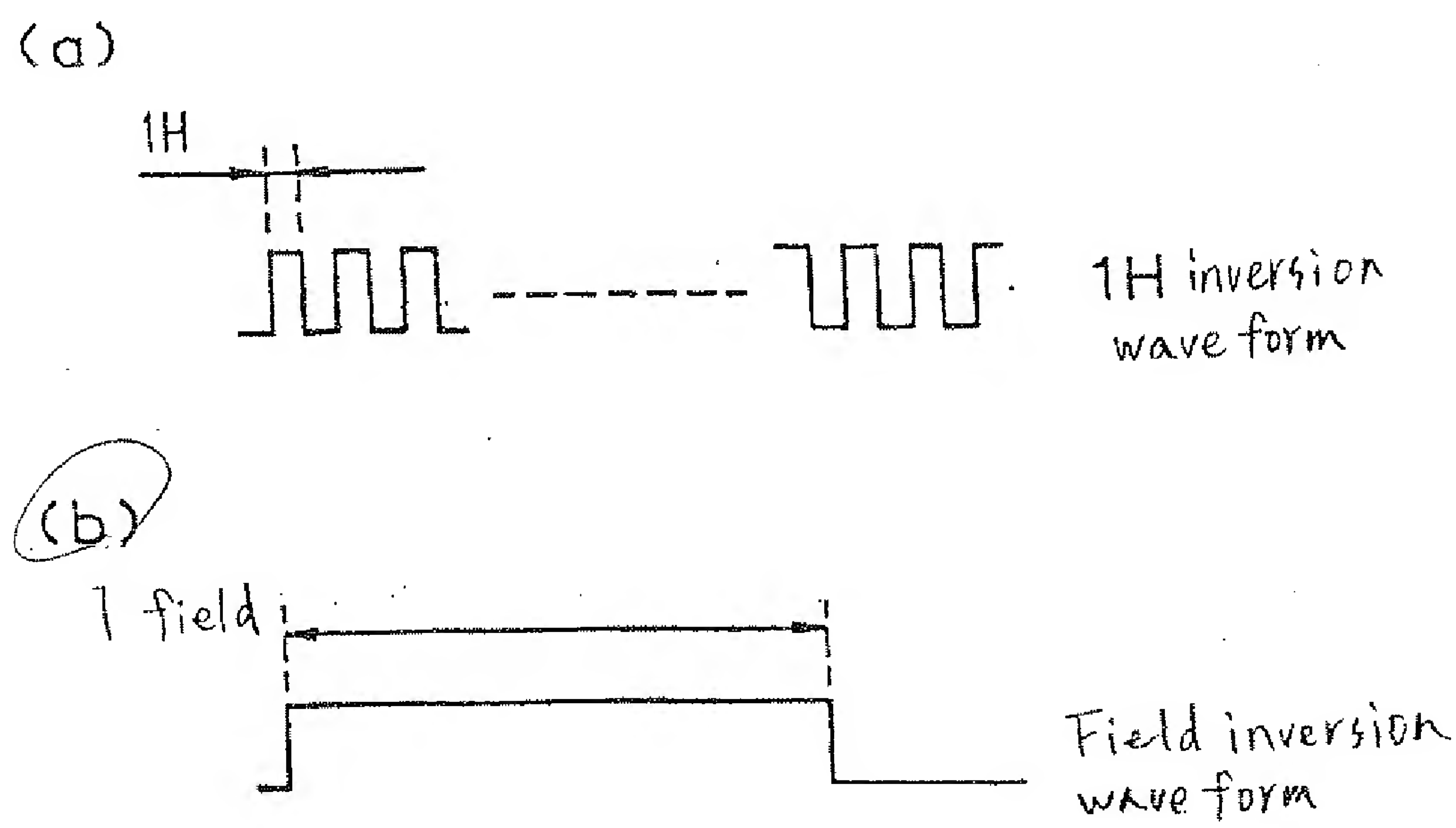
[Fig. 5]



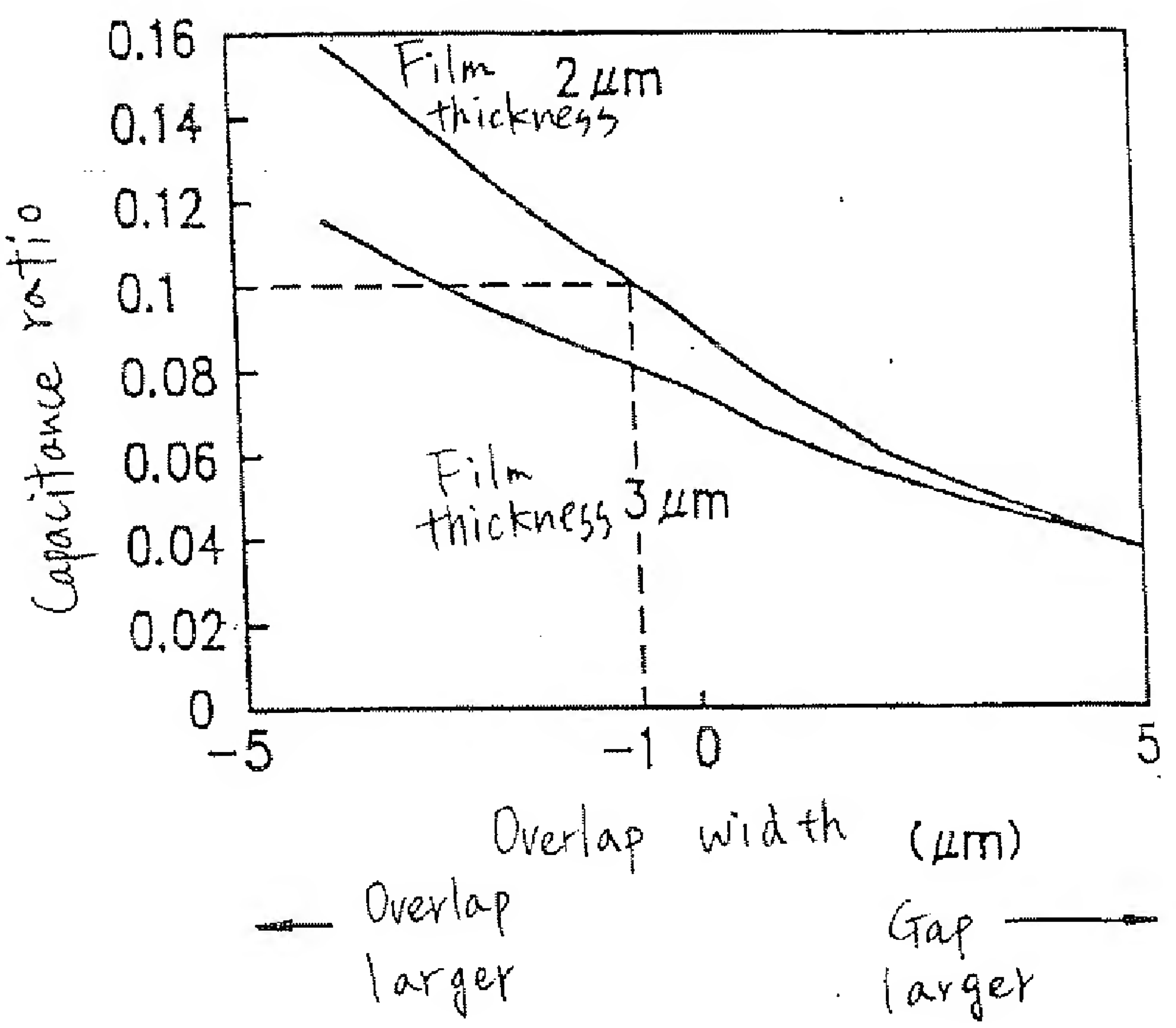
[Fig. 6]


4.00%
3.00%
2.00%
1.00%
0.6%
0
Charging difference
Field inversion (Counter electrode DC)
1H inversion (Counter electrode DC)
1H inversion (Counter electrode AC/5V)
2%
4%
6%
9%
10%
12%
Capacitance ratio

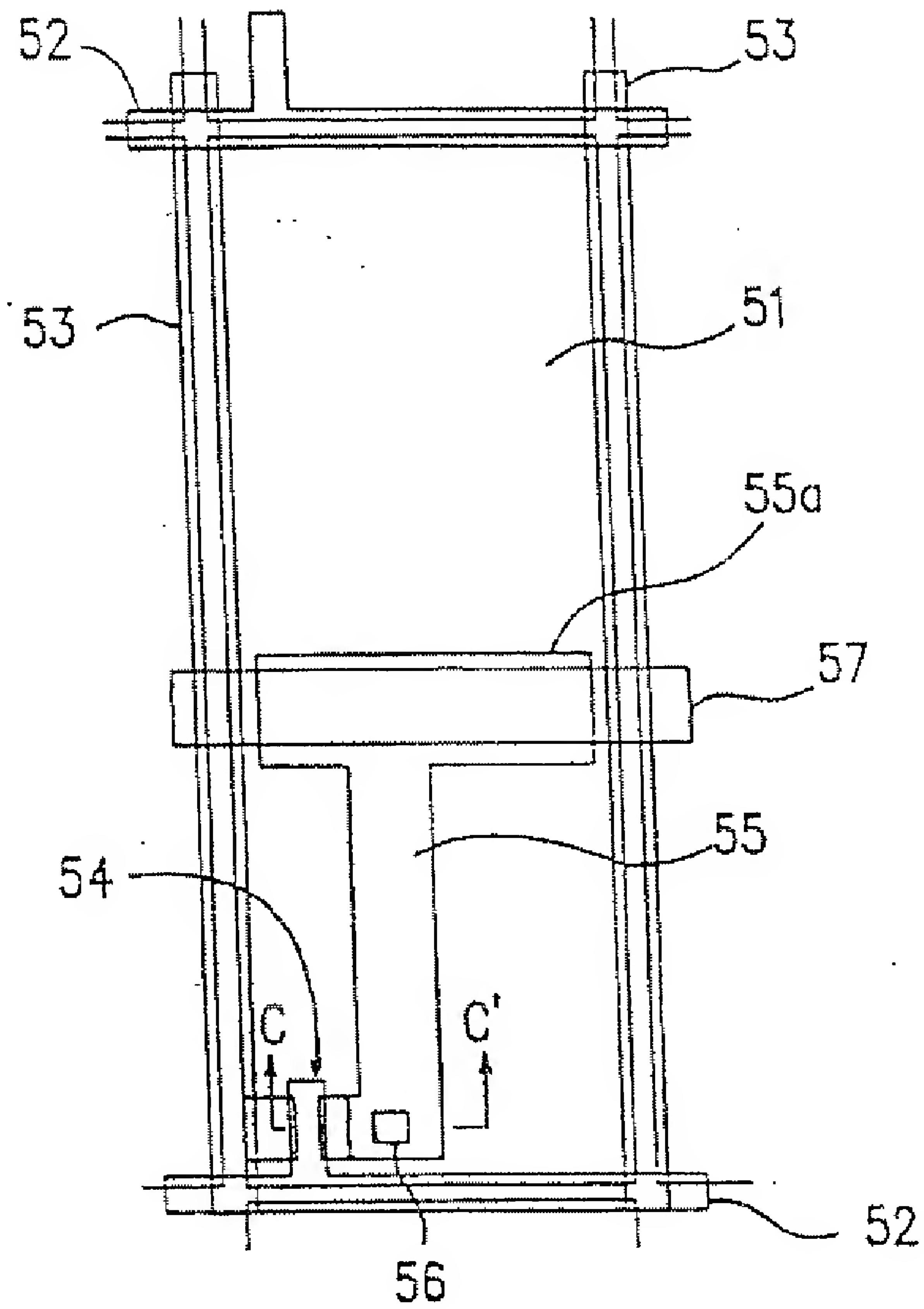
[Fig. 7]


(a)
1H
1H inversion wave form
(b)
1 field
Field inversion wave form

[Fig. 8]


0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Capacitance ratio
Film thickness 2 µm
Film thickness 3 µm
-5
-1
0
5
Overlap width (µm)
Overlap larger
Gap larger

[Fig. 9]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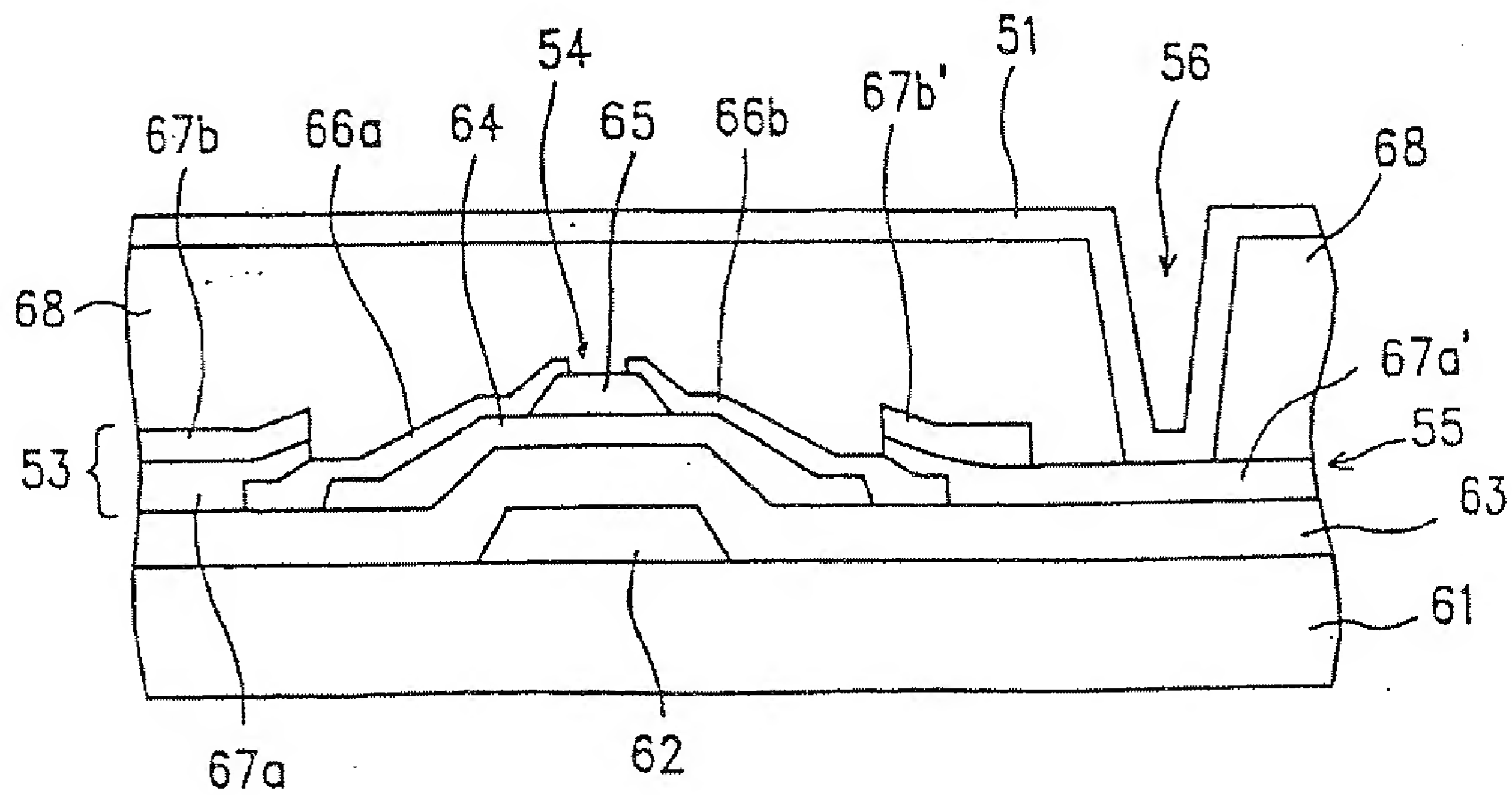
53
53
51
55a
57
55
54
C
C'
52
56

[Fig. 10]


54
51
56
67b
66a
64
65
66b
67b'
68
68
67a'
55
53
63
61
67a
62

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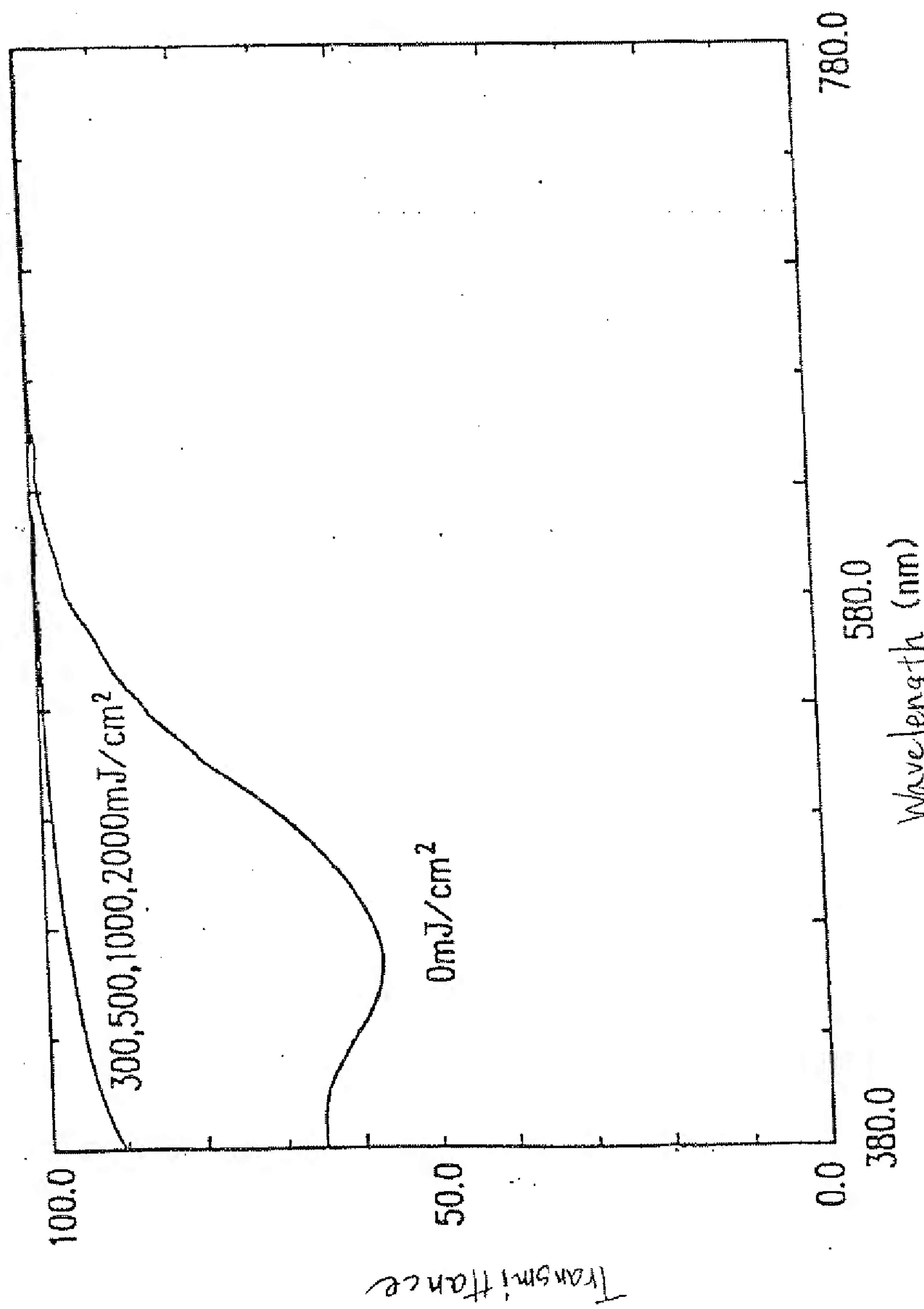
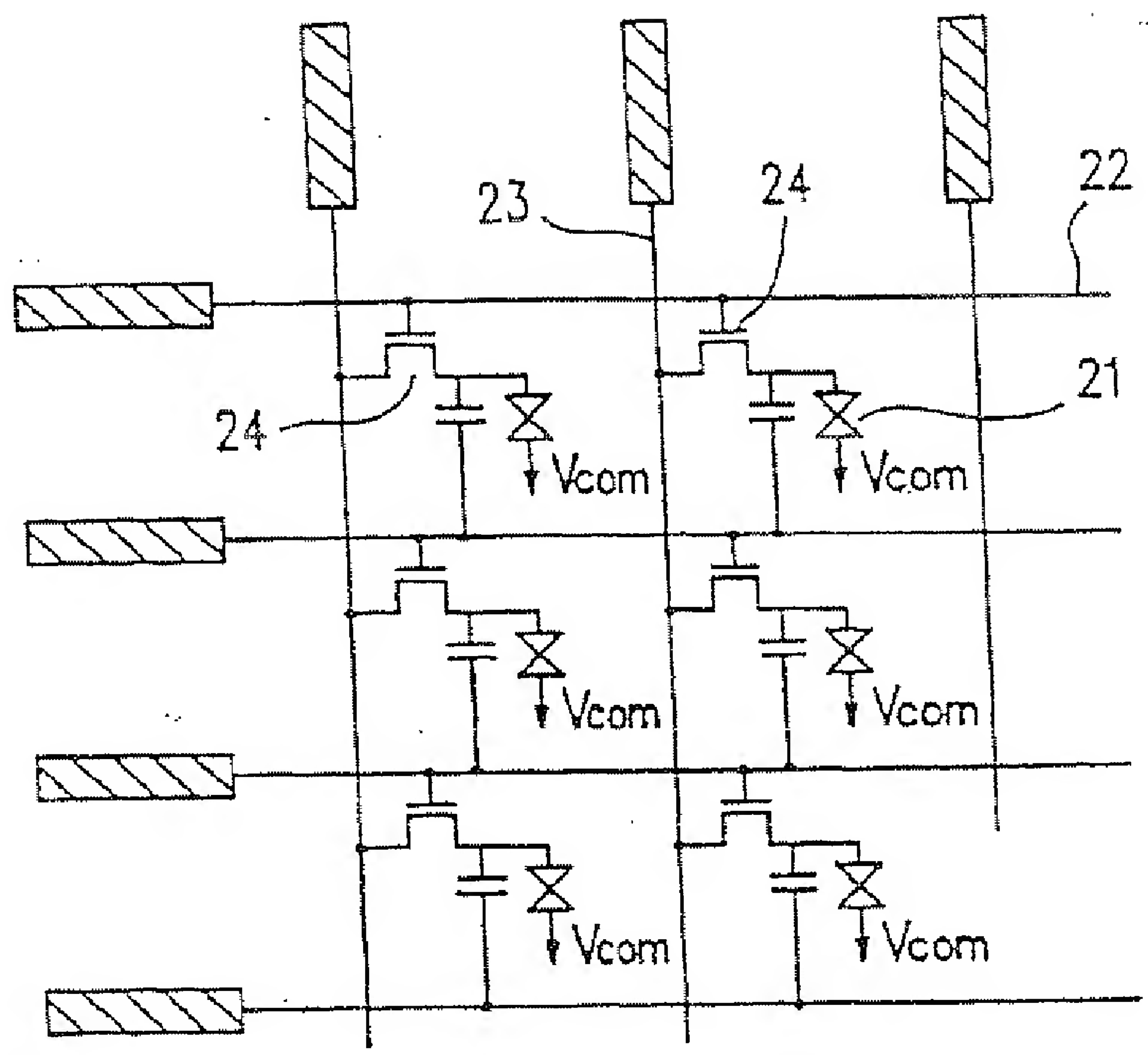
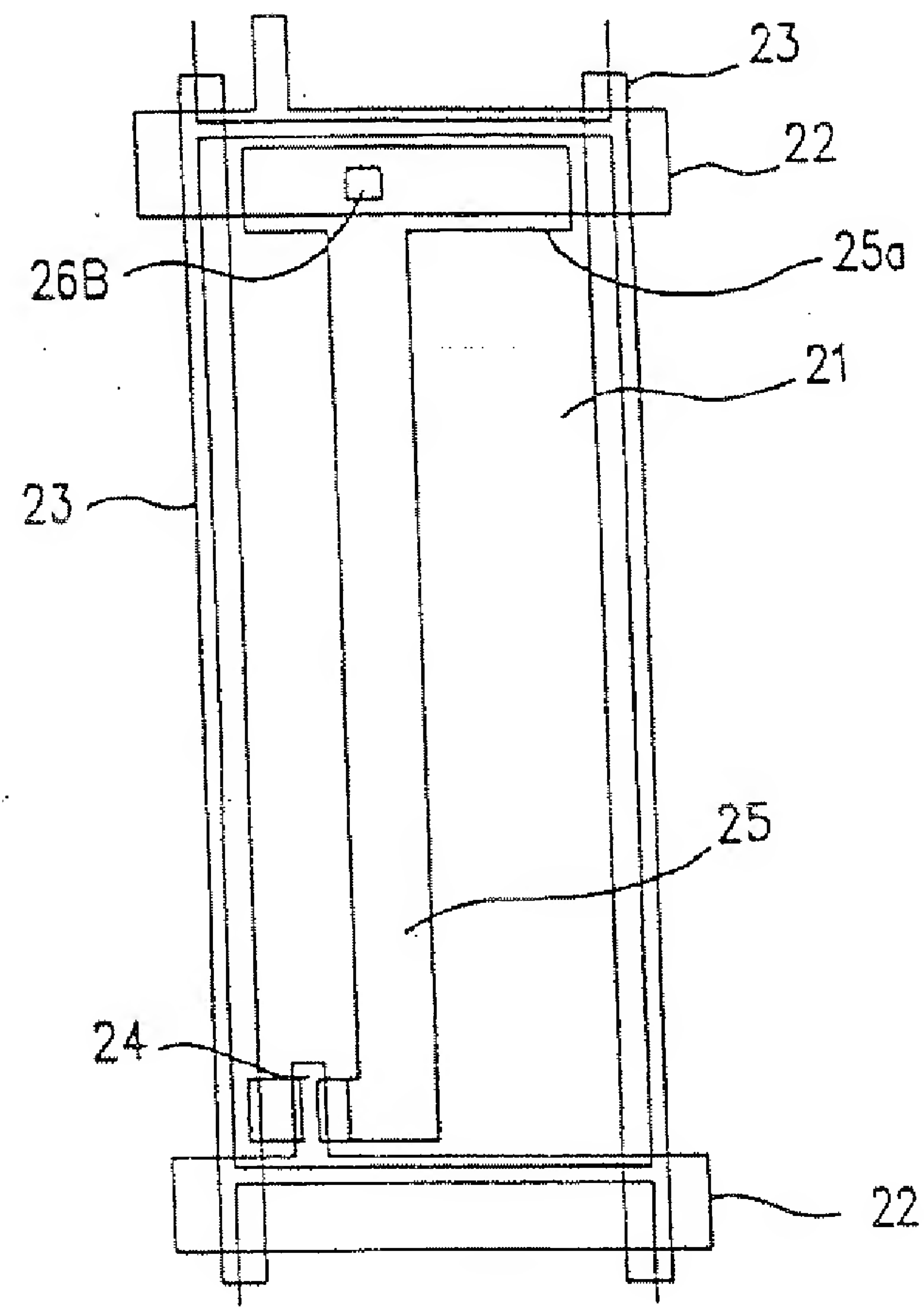
[Fig. 11]



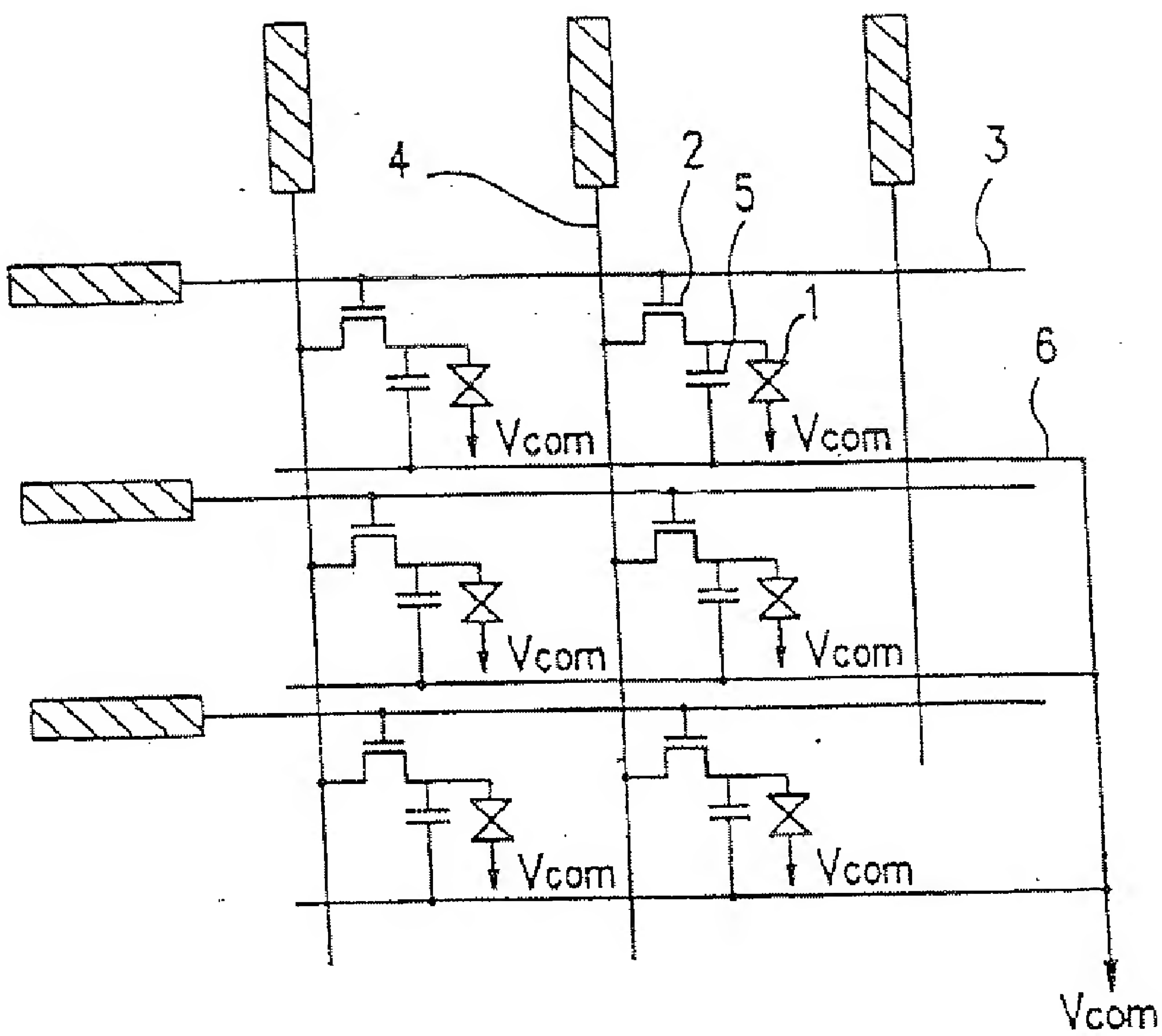
[Fig. 12]



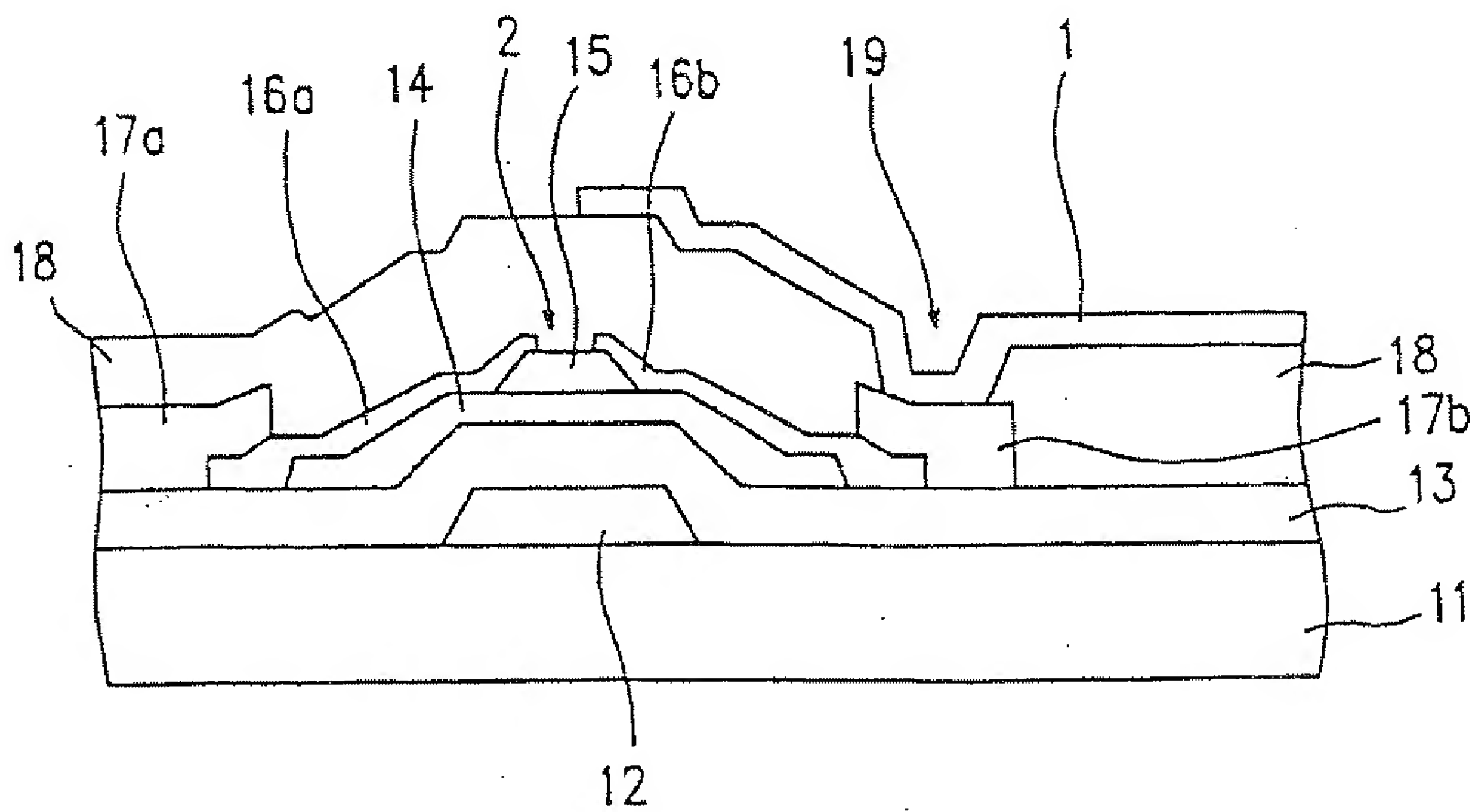
[Fig. 13]



[Fig. 14]


4
2
5
3
1
6
Vcom
Vcom
Vcom
Vcom
Vcom
Vcom
Vcom

[Fig. 15]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16b
19
1
16a
14
17a
18
18
17b
13
11
12

[Name of the Document] ABSTRACT

[Abstract]
[Problem] Each pixel electrode overlaps corresponding lines to improve the aperture ratio while the influence of the capacitance between the pixel electrode and the lines on the display is reduced.

[Means for Solving the Problem] An interlayer insulating film 38 is formed above TFTs 24, gate signal lines, and source signal lines 23, and pixel electrodes 21 are formed on the interlayer insulating film. Each of the pixel electrodes 21 is connected to a drain electrode 36b of the TFT 24 via a connecting electrode 25 and a contact hole 26 formed through the interlayer insulating film 38. The interlayer insulating film 38 is made of an organic thin film such as a photosensitive acrylic resin and has a dielectric constant smaller than an inorganic thin film such as a silicon nitride film. The interlayer insulating film 38 can be easily thickened, to reduce the capacitance between the pixel electrode 21 and the corresponding lines. A transparent conductive film is used for the connecting electrode 25 connecting the drain electrode 36b of the TFT 24 and the pixel electrode 21.

[Selected Figure] Figure 2

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7-254043

[Name of the Document]	Officially Corrected Data
[Corrected Document]	Application for Patent

<Admitted Information • Added Information>

[Applicant for Patent]

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H 16.05.97

7-254043

Applicant's Company History

Identification Number	[000005049]
1. Date of Change	August 29, 1990
[Reason for Change]	New Entry
Address	22-22, Nagaike-cho, Abeno-ku, Osaka-shi, Osaka
Name	SHARP KABUSHIKI KAISHA